PROGRAMME

59th IWK

Ilmenau Scientific Colloquium
Technische Universität Ilmenau

September 11 – 15, 2017

»Engineering for a Changing World«

Department of
Mechanical Engineering

TECHNISCHE UNIVERSITÄT
ILMENAU

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Dear Conference Participants!

We are proud to welcome you to Technische Universität Ilmenau for the 59th Ilmenau Scientific Colloquium (59. Ilmenauer Wissenschaftliches Kolloquium, IWK). As the first IWK was held in 1956, this colloquium is one of the longest continuing conferences in bridging disciplines of and around engineering.

In 2017, the Ilmenau Scientific Colloquium is again organised by the Department of Mechanical Engineering. The title of this year's conference

"Engineering for a Changing World"

refers to limited natural resources of our planet, to massive changes in cooperation between continents, countries, institutions and people – enabled by the increased implementation of information technology as the probably most dominant driver in many fields. The Colloquium, complemented by workshops, is characterised by the following topics, but not limited to them:

- Precision Engineering and Metrology
- Industry 4.0 and Digitalisation in Mechanical Engineering
- Mechatronics, Biomechatronics and Mechanism Technology
- Systems Technology
- Innovative Metallic Materials

The topics are oriented on key strategic aspects of research and teaching in Mechani-cal Engineering at our university. As always in the long series of IWK conferences, we have invited and encouraged contributions from both academia and industry. We are very much pleased with the response. After careful international reviewing, more than 160 contributions remain for presentation, representing 13 contributing coun-tries. The range of subjects certainly reflects the interdisciplinary nature of the con-ference topics and will fruitfully bring together experts from industry and academia. We are confident that the IWK will be the perfect platform for discussion, establish-ing new contacts and for the beginning or continuation of cooperative projects. No matter whether you are an experienced professional or a novice in mechanical engi-neering – we are convinced that the 59th Ilmenau Scientific Colloquium will be of benefit to you.

Besides an enriching and interesting conference, we wish you an enjoyable stay in the town of Ilmenau and its surroundings. The region is the home of the Bach family, and its most prominent member Johann Sebastian Bach in specific, who collected his first professional experiences in this region 300 years ago. Still Thuringia is one of the richest landscapes of classical music worldwide. Perhaps the 59th IWK will inspire you to follow the traces of Bach!

Professor Peter Scharff
President of the Technische
Universität Ilmenau

Professor Christian Weber
Dean of the Department of
Mechanical Engineering

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Monday, 11.09.17 10:00 a.m. - 12:00 noon	Audimax | **Opening Ceremony and Plenary Lectures (Prof. Gräßler | Prof. Osten) Award of honorary Doctorate Degree**											Conference Office Installation Companies
1.30 p.m. - 4.30 p.m.			3.1	1.2								Conference Office Installation Companies
5:00 p.m.	Outside of Humboldtbau | **Welcome Reception for all speakers, participants and guests**											
7:30 p.m.	Humboldtbau | Audimax | **Academic Gala Concert**											
Tuesday, 12.09.17 9:00 a.m. - 12:00 noon	2.2			1.1	4.1	2.3	3.3					Conference Office Visits of Expositions
12:00 noon - 1:30 p.m.	Foyer Humboldtbau | **Poster Session** 1.1, 1.2, 2.1, 2.2, 2.3, 3.1, 3.3											
1:30 p.m.- 4:00 p.m.					2.1			1.2				Conference Office Visits of Expositions
4:00 p.m.	Start from the Mensa (Dining Hall) | **Excursion to Arnstadt | Banquet**											
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1:30 p.m. - 4:30 p.m.		1.3		1.1				3.2				Conference Office Visits of Expositions
1:30 p.m. - 4:30 p.m.	Audimax | **Ehrenkolloquium in memoriam an Prof. Eberhard Kallenbach**											
Thursday, 14.09.17 9:00 a.m. - 12:00 noon	1.4	5						WS 4				Conference Office Visits of Expositions
1:30 p.m. - 4:30 p.m.					WS 3			WS 1	WS 2	WS 2		
12:00 noon - 1:30 p.m.	Foyer Humboldtbau | **Poster Session** 1.4, 3.2, 5											
Friday, 15.09.17 9:00 a.m. - 12:00 noon								WS 1				Conference Office Removal of Expositions

Legend: Sessions of the 59th IWK | Social events of the 59th IWK | Workshops | Kolloquium

Workshop WS1 – Living Glass Surfaces
Workshop WS2 – Virtual Reality
Workshop WS3 – Digitale Mehrkanalbildverarbeitung und -erfassung
Workshop WS4 – Neuartige Anwendungen in der Präzisionskraftmess- und Wägetechnik

Location: HU – Humboldtbau | Gustav-Kirchhoff-Platz 1
EAZ – Ernst-Abbe-Zentrum | Ehrenbergstraße 19

Registration | Conference Office

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Opening hours/ Registration

Monday, 11.09.17	8:00 a.m. – 8:00 p.m.
Tuesday, 12.09.17	8:00 a.m. – 3:30 p.m.
Wednesday, 13.09.17	8:00 a.m. – 5:30 p.m.
Thursday, 14.09.17	8:00 a.m. – 5:30 p.m.
Friday, 15.09.17	8:00 a.m. – 1:30 p.m.

Catering | WLAN-Access | Parking

Coffee break

At the colloquium, refreshments will be offered during the coffee breaks in the foyer of the conference building.

Meals and Refreshments

All participants may take advantage of the catering service in the Mensa (Dining Hall) of the university. You can get there within a few walking minutes from the conference building.

WLAN-Access

Throughout the 59th IWK in all lecture rooms WLAN is available.

SSID: TUI-Guest

You will be redirected to
https://beaker.net.tu-ilmenau.de/login.html

Login: **gltisc2017** Password: **confpart**

Free Parking

On the campus, the signposting system will help you find the way to the conference building (Humboldtbau) easily.

We have reserved for you the parking space right behind the building "Arrhenius" near the conference building. From there, you can reach the Conference building – (Humboldtbau) on foot within a few minutes.

Conference Programme

Opening Ceremony | Plenary

Monday, 11.09.17, 10:00 a.m. – 12:00 noon/ Audimax	Musical opening by Chamber Choir of the Technische Universität Ilmenau under the Conduction of Arne Puschnerus
Moderation:	Professor René Theska Head of Organisation of the 59th IWK
10:10 a.m.	**Welcoming Speeches by:** - Professor Peter Scharff President, Technische Universität Ilmenau - Professor Christian Weber Dean, Department of Mechanical Engineering - Representative of the Thuringian Ministry for Economic Affairs, Science and a Digital Society
10:25 a.m.	**Plenary Lectures** Professor Iris Gräßler | Paderborn University **"A New V-Model for Interdisciplinary Product Engineering"** Professor Wolfgang Osten | University of Stuttgart **"Taking advantage of the whole information content of the light field: Approaches and Limitations in Optical Imaging and Metrology"**
11:30 a.m.	**Award of honorary Doctorate Degree**
12:00 noon	Musical closing by: Erik Kaufmann, Grand Piano Student of the University of Music Franz Liszt Weimar End of Opening Ceremony and Plenary

10:25 a.m.	Plenary Lecture I. Gräßler (D-Paderborn)

A New V-Model for Interdisciplinary Product Engineering

Within the Technical Committee VDI GMA 4.10 "Interdisciplinary Product Creation" of the Association of German Engineers (VDI), the revision of the directive VDI 2206 "Development methodology for mechatronic systems" is being worked out since the beginning of 2016. The core of the guideline is the V-model describing the mechatronic engineering process as a macro-cycle [1]. A core team of industrial and academic members collected impulses of rework and additions and implemented them in the new and extended V-model. The new approach comprises continuous requirements elicitation and management, comprehensive modeling and analysis and the emphasis on the product life cycle. The proposed revision of the V-model unites the models of different development methodologies, e.g. VDI 2221 [3], Systems Engineering [4] and elements of the previous VDI 2206 [2]. The next step in the revision work will be a validation workshop on the actual status of the V-Model.

Literature

[1] Verein Deutscher Ingenieure (VDI), *VDI 2206 – Design Methodology for Mechatronic Systems, Düsseldorf, 2004*

[2] I. Gräßler, J. Hentze, X. Yang – Eleven potentials for mechatronic V-model, 6th International Conference on Production Engineering and Management, September 29/30th, 2016, Lemgo

[3] Verein Deutscher Ingenieure (VDI), *VDI 2221 – Systematic Approach to the Development and Design of Technical Systems and Products, Düsseldorf, Mai 1993 and „Gründruck" of revised version in 2017*

[4] U.S. Department of Transportation (DoT) - *Systems Engineering Guidebook for Intelligent Transportation Systems,* Version 3.0, California, 2009

Topic 1

Precision Engineering and Metrology

Session 1.1 | Precision Measurement Technology
Session 1.2 | Measurement and Sensor Technology
Session 1.3 |Precision Engineering and Optics
Session 1.4 | Optics for Illumination, Imaging and Metrology

Session: 1.1 Precision Measurement Technology

Time: Tuesday, 12.09.2017
Location: Humboldtbau | Humboldt Lecture Hall
Chairmen: E. Manske (D-Ilmenau | L.-C. Chen (TW-Taipei)

9:00 a.m.	Invited Lecture W. Jywe (TW-Yunlin)

The calibration and compensation techniques for 5 axes CNC machine tools

9:30 a.m.	E. Manske, T. Fröhlich, S. Sinzinger, I. Rangelow, R.. Füßl, J. Reger, M. Hoffmann, C. Schäffel, M. Kühnel (D-Ilmenau)

Alternative nanofabrication on the base of nanopositioning and nanomeasuring machines

10:00 a.m.	G. Dai, P. Liu, L. Koenders, J. Flügge, M. Hemmleb (D-Braunschweig)

Fast and accurate: high-speed metrological large range AFM for surface and nanometrology

Low measurement speed remains as a major shortcoming of the scanning probe microscopic techniques. It leads not only to a low measurement throughput, but also to a significant measurement drift over the long measurement time needed (up to hours or even days). In this paper, development of a high speed metrological large range atomic force microscope (HS Met. LR-AFM) with a capable measurement speed up to 1 mm/s is presented. In its design, a high accurate nanopositioning and nanomeasuring machine (NMM) is combined with a high dynamic flexure hinge piezo stage to move sample. The AFM output signal is combined with the position readouts of the piezo stage and the NMM to derive the surface topography. This design has a remarkable advantage that it well combines different bandwidth and amplitude of different stages/sensors, which is required for high speed measurements. While the HS Met. LR-AFM significantly reduces the measurement time while maintains (or even improves) the metrological performance than the previous Met. LR-AFM, its application capabilities are extended significantly. Two application examples, the realisation of reference areal surface metrology and the calibration of a kind 3D nano standards, have been demonstrated in the paper in detail.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions

10:40 a.m.	Y. Hirniak, O. Ivakhiv, M. Nakonechnyi (UA-Lviv)

Using artificial neural networks to study the dynamics of positioning systems

In this paper the usage of the artificial neural networks instruments for the positioning systems development and for studying its dynamics are described. The described transition from linear differential dynamic equation to architecture of neural network, which reproduces it, ensures the applicability of functional analogy between the structure of linear neuron and the structure of digital filter. These methods are applicable for the many kind of

controlled systems, both the homogenous and hybrid type regarding mixing mechanical, electrical, end other types of parts used. In currently researched systems a good reliability of the simulation results are achieved. The described methods are implemented mostly by means of MATLAB environment with the aid of CAD software.

11:00 a.m.	R. Schienbein, R. Theska, F. Weigert (D-Ilmenau)

A contribution to the implementation of ultraprecision rotations for multiaxial nanopositioning machines

Existing long range nanopositioning and nanomeasuring machines are based on three independent linear movements in three rectangular axes. This in combination with the specific nature of optical and mechanical sensors and tools limits the application of those machines in terms of addressable part geometries. State of the art multiaxial precision machines solve this problem but do not fulfil the requirements in positioning accuracy. This article contributes to the development of multiaxial machine structures allowing e.g. 5-axis operation while keeping the precision in the nanometre range. A parameter based dynamic evaluation system with quantifiable technological parameters is performed to identify general solution concepts. State of the art machines are evaluated based on this classification system in terms of the implementation of multi-axial movements. The evaluation system is further refined with comprehensive design catalogues and corresponding diagrams to support the selection of adequate substructures. First evaluations for the substructure in terms of a rotation axis for the probing system of a nanopositioning machine in its XZ-plane show the highest degree of fulfilment for basic structures considering a goniometer setup. After all, the knowledge gained is formed into general rules for the verification and optimization of constructive solutions for multiaxial nanopositioning machines.

11:20 a.m.	J. Riebeling, P. Lehmann (D-Kassel), S. Laubach, G. Ehret (D-Braunschweig)

Combination of a fast white-light interferometer with a phase shifting interferometric line sensor for form measurements of precision components

Modern industrial fabrication processes put high requirements on the quality of the surface form of precision-machined components, e.g. optical lenses or microelectromechanical systems (MEMS). Optical sensors provide high precision non-contact surface measurement to verify these quality requirements, even on fragile surfaces.

The low-cost line-scanning interferometer that is presented in this contribution is based on a Michelson interferometer configuration in combination with a high-speed line-scan camera. The sensor can operate in scanning white-light or in optical path length modulation (OPLM) mode. The white-light mode is used to automatically align the sensor perpendicular in the working distance of 13 mm to the surface of the specimen. In OPLM-mode, an oscillating reference mirror and a band-pass filtered light source are used, to measure the form of a radial symmetric specimen with a diameter of up to 25.4 mm with interferometric

accuracy. Several overlapping ring-shaped sub-apertures are measured iteratively in different radial positions until the whole surface is scanned. The sub-apertures are stitched together to reconstruct the complete 3D-topography, while overlapping areas can be used to correct movement errors of the scanning axes. This concept is highly adaptive and can be applied to many different specimen geometries e.g. planes, spheres or aspheric glass lenses.

11:40 a.m.	S. Gorges, B. Leistritz, S. Hesse, I. Ortlepp (D-Ilmenau), G. Slotta (D-Unterhaching), C. Schäffel (D-Ilmenau)

Development of an integrated guiding and actuation element for high dynamic nanopositioning systems

In this paper, the development of an integrated guiding and actuation element for the vertical actuation in nanopositioning systems is presented.

The basic idea is the combination of a planar air bearing pad with a vertical drive unit that comprises electromagnetic actuation and aerostatic guiding of the vertical movement together with pneumatic weight compensation. The weight compensation works on the basis of a pressure chamber while the pressure is permanently adapted to the actual load situation. Thus, the electromagnetic actuator only has to apply a dynamic force, reducing the overall heat dissipation. An air bushing provides frictionless guiding for the vertical movement. The vertical drive unit is placed concentrically on top of a planar air bearing pad so that the system as a whole will provide frictionless planar and vertical guiding together with direct vertical actuation.

In this configuration it represents a crucial enhancement for a planar nanopositioning system with aerostatic slider support and an integrated direct drive for the actuation in x, y and phi z. On the basis of the engineering design for a first prototype, the paper introduces the concept of the integrated guiding and actuation element, the intended parameters and describes the design, the arrangement and the interaction of the main components. The results of the initial operation are presented together with the corresponding conclusions and main goals for future research.

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions
12:00 noon – 1:30 p.m. Poster Session | Foyer Humboldtbau

Session 1.1 Precision Measurement Technology

Time: Wednesday, 13.09.2017
Location: Humboldtbau | Humboldt Lecture Hall
Chairmen: R. Füßl (D-Ilmenau) | G. Dai (D-Braunschweig)

9:00 a.m.	Invited Lecture L.-C. Chen, C.-W. Liang, D.-C. Hoang, S.-T. Lin (TW-Taipei)

Accurate surface edge profilometry using novel adaptive edge search algorithm

9:30 a.m.	A. Yacoot (GB-Teddington), P. Klapetek, P. Grolich, M. Valtr, D. Necas (CZ-Brno), H. Dongmo, E. Oertel, M. Lazzerini (GB-Teddington)

Error mapping of position and intelligent data scanning for atomic force microscopy

9:50 a.m.	C. Weichert (D-Braunschweig), P. Köchert (D-Ilmenau), E. Schötka, J. Flügge (D-Braunschweig), E. Manske (D-Ilmenau)

A straightness measuring interferometer characterized with different wedge prisms

Independently of the component used to introduce a divergence angle between the two probing beams of straightness interferometers, their uncertainty is limited by three main errors linked to each other: their resolution, the influence of refractive index gradients and the topography of the straightness reflector. The larger the divergence angle the higher is the resolving capability, but also the potential influence of the other two error sources. A fully fibre-coupled heterodyne interferometer was successively equipped with three different wedge prisms to investigate the optimal divergence angle under laboratory conditions. For that, the straightness interferometer was qualified with the Nanometer Comparator, which is a one-dimensional line scale interferometer with an additional straightness measurement capability. This feature is based on the traceable multi-sensor method, where an angle measurement embodies the "straightedge". Therefore, the qualification of the straightness interferometer was also a comparison of two different straightness measurement methods. The influence of the refractive index gradients of air did not increase with interspaces between the probing beams larger than 11.3 mm. Therefore, over a movement range of 220 mm, the lowest uncertainty was realized with the largest divergence angle. The dominant uncertainty contribution arose from the uncorrected mirror topography determined with sub-nanometre uncertainty with the Nanometer Comparator.

10:10 a.m.	F. Siewert, J. Buchheim, G. Gwalt (D-Berlin), J. Viefhaus (D-Hamburg)

On the characterization of ultra-precise VUV-focusing mirrors by means of slope measuring deflectometry

Slope measuring deflectometry allows the non-contact measuring of curves surfaces like ultra-precise elliptical cylinder shaped mirrors in use for the focusing of Synchrotron light.

This paper will report on the measurement of synchrotron mirrors designed to guide and focus Synchrotron light in the variable polarization beamline P04 at the PETRA III synchrotron at DESY (Hamburg). These mirrors were optimized by deterministic finishing technology based on topography data provided by slope measuring deflectometry. We will show the results of the mirror inspection and discuss the expected beamline performance by ray-tracing results.

10:30 - 10:45 a.m. Coffee break and Visits of Expositions	
10:45 a.m.	Y. Shimizu, T. Maruyama, S. Nakagawa, Y.-L. Chen, W. Gao (JP-Sendai)

Evaluation of a focused laser spot diameter for an optical angle sensor

Fabrication accuracy of precision products such as free form optics is determined by the positioning accuracy of positioning systems to be used in ultra precision machine tools. High precision displacement sensors often employed for the closed-loop control of a positioning system. Meanwhile, most of the positioning systems have an offset between its measurement axis and the motion axis, which is referred to as the Abbe offset, resulting in a positioning error. Although some novel positioning systems are designed to comply with the Abbe principle, in most of the cases, the angular error motions of positioning systems are required to be measured to achieve further higher positioning accuracy. Laser autocollimators employing photodiodes (PDs) as its optical detectors are suitable for measurement of stage motions. By using a quadrant photodiode, two-degree-of-freedom tilt can be measured simultaneously. Meanwhile, the sensitivity of angle sensor can be improved by reducing the diameter of focused laser beam on the PDs. The employment of single cell photodiodes can accept further smaller focused laser beam to achieve further higher sensitivity. In this case, the evaluation of the diameter of focused laser beam is important. In this paper, a new method for the measurement of the diameter of focused laser beam is proposed, and some experiments are carried out to verify the feasibility of the proposed method.

11:05 a.m.	H.-T. Shih (TW-Taoyuan), Y.-C. Wang, L.-H. Shyu (TW-Yunlin), P.-C. Tung (TW-Taoyuan), W.-Y. Juwe, J.H. Chen (TW-Yunlin)

Automatic calibration system for Micro-displacement Devices

With the industrial development and the advances in micro - displacement technology, the demands on piezo transducers are increasing. For piezo transducers, the error inspections of the non-linearity and the hysteresis are necessary procedure before piezo transducers utilized. Due to the possible decline or damage during the employment of the transducers, it is important to provide the automatic calibration system.

In this investigation, a self-developed automatic calibration system for micro-displacement devices is proposed. The automatic system according to the international specification of ASTM-E2309 has been developed. This system designed for the calibration of piezo transducers is based on the interferometric structure of the common optical path and possesses the resolution of the nanometer order. The experimental verifications demonstrate that the repeatability of the Fabry-Perot interferometer is less than 11 nm.

Experimental results of the synchronic measurement with the self-developed interferometer and a commercial interferometer reveal that the differences of the maximum nonlinearity error and maximum hysteresis error are less than 1%. With the proposed correct equations, the maximum non-linearity error can be minimized to 1% and the maximum hysteresis error will be less than 5.2%.

11:25 a.m. | N. Loftfield, M. Kästner, E. Reithmeier (D-Hannover)

3D Reconstruction and Characterization of the Porous Microstructure of Al2O3-Coatings Based on Surface Data

The functionalities and properties of components strongly correlate to the material's structure and the microstructure of the surface. Therefore, by characterizing the structure of a material or surface information is indirectly gained on its properties. The objective of this research is to manufacture and characterize porous aluminum oxide surface coatings with high wear resistance and active friction minimization. This is approached by embedding a channel system beneath the surface, which is to serve as a reservoir for lubricants. The functionality of the coating depends on the porous structure: on the one hand on the surface of the coating and on the other hand the porous structure in the material. Namely, the tribological behavior correlates with the surface structure and the fluid flow in porous media strongly dependents on morphological and topological parameters like the pore size and shape and the pore connectivity. So, to gain meaningful information on the coatings properties, we present a new approach to gain 3D measurement data of porous structures by reconstructing the porous material. This is implemented in an alternating process of milling the surface and measuring the surface data. Based on the surface height data, a subsequent registration process to align the acquired data and a pore boundaries detection the three dimensional porous structure of the material is reconstructed.

11:45 a.m. | S. Matthias, M. Kästner, E. Reithmeier (D-Hannover)

Pattern sequences for fast absolute phase retrieval with application in the handheld operation of structured light sensors

Areal 3D scanners based on structured light projection are widely used for inspection tasks in manufacturing processes. For accurate measurements of object geometries, common structured light sensors project a sequence of periodic patterns onto the surface. By subsequent evaluation of these patterns, the local phase of the patterns is reconstructed in a phase retrieval step. The local phase encodes the geometry information and allows for the reconstruction of 3D point clouds in combination with a calibration of the sensor. However, motion of an object during the projection of the pattern sequence leads to large deviations in the reconstructed local phase and thus the 3D point cloud. For dynamic measurements of moving objects, several single-shot techniques have been proposed. While these techniques only require a single pattern for 3D measurements, phase reconstruction suffers when measuring non-diffuse reflective surfaces. In order to evaluate the feasibility of different

approaches, sequences of periodic patterns with different lengths are compared based on static and dynamic measurements of a contour standard with a non-diffuse surface using a fiber-endoscopic structured light sensor. A proof of concept of simultaneous localization and mapping for the handheld operation of the endoscopic sensor head is demonstrated, which can be used for the navigation in narrow spaces in the future.

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions

Session 1.1 Precision Measurement Technology

Time: Wednesday, 13.09.2017
Location: Humboldtbau | Humboldt Lecture Hall
Chairmen: A. Yacoot (GB-Teddington) | F. Siewert (D-Berlin)

1:30 p.m.	Invited Lecture A. Schütze (D-Saarbrücken)
Condition monitoring of Industrial Processes and based on Smart sensors	
2:00 p.m.	C.-S. Chen (TW-Taipei)
The Stitching Technique Using Harris 3D Feature Points Based on Dual Laser Scanning Point Cloud	
2:20 p.m.	V. Ullmann (D-Ilmenau), T. Meß (D-Schmalkalden), K. Wenzel (D-Ilmenau), T. Machleidt (D-Ilmenau), E. Manske (D-Ilmenau)
A new approach for holistic thread profile determination supported by optical focus variation measurements In this proceeding a new approach for the description of geometric-real threads will be given. The holistic determination of the virtual pitch diameter depends on the whole thread scanning. For this purpose, the optical focus variation system, consisting of a microscope objective and a digital camera, captures a stack of pictures and reconstructs the thread surface by a contrast analysis between neighbored pixels. A special calibration gauge for the focus variation system was designed and tested. The traceability and the measurement uncertainty for 3D-Points in precision thread gauge measurements will be given. The uncertainty in the current measurement setup is $<0.6\ \mu m$ in each coordinate direction (x, y, z) for a S11.2 thread.	
2:40 p.m.	R.-J. Li, Y.-J. Lei, L.-S. Zhang (CN-Hefei), K.-C. Fan (TW-Taipei), Z.-Y. Cheng, P.-H. Hu (CN-Hefei)
Low-Frequency Micro/Nano-vibration Generator Using a Piezoelectric Actuator Low-frequency vibration must be detected because of its harmful effects on micro/nano measuring machines. Thus, the authors developed a low-cost and high-precision detector for low-frequency micro-vibration. A high-precision vibration generator is required to calibrate the vibration detector because of the high cost and complex structure of existing vibration generators. A new vibration generator that can produce low-cost and high-precision low-frequency vibration was also developed. A piezoelectric actuator is used as a vibration exciter, which is driven by a high-precision signal generator and a high-voltage amplifier. A beryllium bronze-based leaf spring was used as an elastic component, which is optimally designed and verified by the ANSYS software.	

The proper size and natural frequency of the leaf spring were obtained. The leaf spring was fixed horizontally on a four-point cylinder-shaped pedestal and driven by the actuator vertically. The worktable on the top surface of the leaf spring only had an up-down direction. A high-precision eddy current sensor was used to test the performance of the vibration generator. Experimental results show that the vibration generator can produce simple harmonic vibrations with a frequency and amplitude ranges of 10–50 Hz and 0.90–19.87 μm, respectively, and the repeatability of the open-looped vibration amplitude is less than 90 nm (K=2). The developed vibration generator can be used when a micro/nano-vibration detector is calibrated.

3:00 – 3:15 p.m. Coffee break and Visits of Expositions

3:15 p.m.	D. Dontsov, I. Rahneberg, E. Langlotz, W. Schott (D-Ilmenau)

Dynamic alignments and calibration of linear axis

Linear positioning axes are used as basic assemblies in a wide range of applications in manufacturing, and measurement technology, such as in machine tools and coordinate measuring machines. If linear axes are installed in machines and devices, the accuracy of the complete system is limited by the rotational and translatory deviations of the individual axes from the ideal linear path of motion. The highly accurate, dynamic detection of the guiding properties during mounting and alignment of these system components is consequently the key to achieving minimal positioning deviations of the assembled system.
The presented devices for the alignment and calibration of linear axes are based on laser interferometric measuring methods. They enable highly accurate simultaneous measurements of linear position, pitch and yaw angles as well as a straightness component in one measurement run. The particular measurement methods for dynamic measurements during alignment are described and the impact on the results of alignment and machine performance are discussed. The same devices that are used during alignment and assembly are also applicable as calibration interferometers which allow position measurements up to 50 m. The particular requirements concerning measurement setup and environmental parameter measurement to achieve accuracies of 1·10-7 are explained on the basis of practical examples.

3:35 p.m.	F. Balzer, N. Steffens (D-Wetzlar), M. Stein, K. Kniel (D-Braunschweig)

Traceable measurement of large gears with micron accuracy - A mandatory basis for reliable wind energy systems

The production of highly accurate components of renewable energy systems such as Wind Energy Systems (WES) puts mandatory constraints in the verification procedures related to 3-D geometry for the tolerance of size, form, waviness and roughness. More information concerning geometric flank deviations and surface roughness properties are requested.
This paper focuses on the calibration and measurement of large gears used in gearboxes of WES. One major issue ensuring traceability is the lack of appropriate gear measurement

standards. One large ring gear measurement standard was recently developed by the Physikalisch-Technische Bundesanstalt (PTB). The ring gear and its calibration on a commercial coordinate measurement machine (CMM) are described. The calibration has been conducted by PTB using the M3D3 method. Tactile measurement results are presented and put into context with calibration values. Furthermore, optical measurement results using a new Hexagon interferometric point sensor are presented and compared to the tactile values.
These results serve as the basis for installing the first accredited calibration laboratory for large gears at BIMAQ in Bremen. In addition, these preliminary investigations into large gear measurements are the basis for installing the first large CMM equipped with multi purpose technology in the competence centre WIND at PTB. Both calibration facilities will help to close the existing gap in the traceability chain for large-scaled gear measurements.

3:55 p.m.	T. Widmaier (FI-Aalto), B. Hemming (FI-Espoo), J. Juhanko, P. Kuosmanen (FI-Aalto), V.-P. Esala, A. Lassila, P. Laukkanen (FI-Espoo)

Using Monte Carlo Simulation for estimation of uncertainty of four point roundness measurements of large rotors

Large scale rotors in the paper and steel industry are called rolls. Rolls there are periodically reground and roundness measurements are made throughout the machining process. Dimensional measurement systems for large rolls (diameter < 2000 mm) are available on the market. They are typically based on the roundness measurement algorithm from Aoki and Ozono. This method can separate roundness of the rotor from its movement. For reliable measurement results, every measurement should be traceable with an estimation of measurement uncertainty. Therefore, three different material standards in the form of discs (diameter > 500 mm) with different roundness profiles were and will be made during this research. They will be measured at least in the laboratories of two national metrological institutes. Later the discs can be used to calibrate measurement devices. In first tests with one of the discs measurement results of two different measuring devices were compared with measurement results from the coordinate measurement machine of the Finnish national metrology institute. They showed deviation in amplitudes of the harmonics to be 2.3 μm or less. This shows that reliable roundness measurements of rolls are possible.

End of Session

D. Imkamp, A. Gabbia (D-Oberkochen), J. Seewig (D-Kaiserslautern)

Alternative Evaluation Methods for Roundness Measurements

Requirements to roundness tolerances are a part of the geometrical product specifications. However, the definition for the roundness tolerance according to ISO 1101 considering radial deviations only is not sufficient to assure the functionality of many products. In addition, the form of roundness deviations along the circumference plays a significant rule for rotating machine components. Especially periodic deviations cause vibrations that lead to noise and wear. The Fourier analysis and the corresponding amplitude spectrum deliver information about the properties of the form derived from the magnitude of the different harmonics. This information presents a series of results depending on the harmonics. Therefore, a dedicated tolerance definition in most cases in from of a mathematical equation is used. The currently used tolerance definitions are not standardized and difficult to understand. Often, only one amplitude of the spectrum is significantly larger than the others are and effects functionality. In this case, an algorithm that detects the largest amplitude enables an easier tolerance definition. The definition for the so-called dominant roundness waviness is simpler because it can be defined by tolerance limits for dedicated parameters. Measurement results form a coordinate measuring machine for dominant roundness waviness on at multi-wave standard show the ability of these machines to perform roundness measurements.

O. Dannberg, I. Ortlepp, E. Manske (D-Ilmenau)

FPGA-based Signal Processing of a Heterodyne Interferometer

A heterodyne interferometer and a data acquiring algorithm have been developed to measure the movement of a mirror in one dimension, as well as its rotation around two axis. The interferometer uses spatially separated beams to reduce periodic optical non-linearities, furthermore the optical set-up was designed for low drift, few number of optical elements and easy adjustment. The FPGA-based signal processing is based on an undersampling technique with the aim to minimise the calculation effort. The working principles of the interferometer and the electronics are described and their remaining non-linearities are investigated. Finally, the z-position, the tip and tilt angle of a planar stage are measured with the described system as an example of use.

H.-T. Shih (TW-Taoyuan), Y.-C. Wang, L.-H. Shyu, B.-Y. Lee, J.-C. Lin, J.-S. Li (TW-Yunlin)

Optimization of the optical parameters in Fabry-Perot interferometer

Due to insensitivity to the environmental disturbances, Fabry-Perot interferometers are suitable for displacement measurements under ordinary conditions. In the structure of folded Fabry-Perot interferometer, the results of the signal subdivision are affected by the optical parameters in the resonant cavity. In this paper, the analysis of the Fabry-Perot interferometer for the measurement of the micro-displacement and the long-distance are investigated. By considering the reflectance of the planar mirror and the intensity loss in the resonant cavity, the parameters of systematic optimization which are suitable for the measurement of the micro-displacement and the long-distance are proposed. The experimental and simulated results reveal that the intensity loss in the resonant cavity is 86% and the optimized reflectance of the planar mirror is 12%.

Session 1.2 Measurement and Sensor Technology

Time: Monday, 11.09.2017
Location: Humboldtbau | Humboldt Lecture Hall
Chairman: F. Härtig (D-Braunschweig)

1:30 p.m.	C. Rothleitner, L. Günther, D. Knopf, F. Härtig (D-Braunschweig), J. Schleichert, S. Vasliyan, N. Rogge, T. Fröhlich (D-Ilmenau)

The Planck-Balance – A self-calibrating precision balance for industrial Applications

A self-calibrating balance is proposed, which allows the calibration of weights in a continuous range from 1 mg to 1 kg. This so-called Planck-Balance (PB) is similar to the physical approach of Kibble Balances that allow the mass to be derived from the Planck constant. Using the Planck-Balance no calibrated mass standards are required during weighing processes any longer, because all measurements are traceable to the electrical quantities and the Planck constant. This allows a new approach of balance types after the expected redefinition of the SI-units by end of 2018. In contrast to many scientific oriented developments, the PB is focused on industrial use. Therefore, two balances will be developed, a PB2 and a PB1, which will allow a relative measurement uncertainty (k = 2) of 5.3 x 10-7 and 1.7 x 10-7, respectively. Those aimed accuracies refer to the class E2 and E1 weights, as specified in OIML R 111-1. The balances will be developed in a cooperation of the PTB and TU Ilmenau in a project funded by the German Federal Ministry of Education and Research. The project started in January 2017 and will run for 3 years.

1:50 p.m.	J. Schleichert, S. Vasilyan (D-Ilmenau), L. Günther (D-Braunschweig)

Magnet system for the Planck-balance

The current definition of the unit kilogram by an artifact is about to be replaced by a definition based on a fundamental constant, which is the Planck constant. To establish the link between a mass standard and the Planck constant an instrument called Watt- or Kibble-Balance can be used. This instrument uses a virtual equilibrium between mechanical and electrical power to connect the mass to the electrical quantities which can be defined from the Planck constant using the Josephson- and the Quantum-Hall effect. After the redefinition of the unit, the new definition can be realized not only for masses of 1 kg but for any arbitrary mass value. Consequently the new definition can be directly applied to weighing processes in industry if a suitable measurement system exists.
In this paper we briefly describe the design of such a weighing system, called the Planckbalance PB2 which is designed to realize the new definition in a mass range from
1 mg to 100 g. In accordance to our theoretical estimations we aim for achieving uncertainties comparable to current mass disseminations using calibrated weights of class E2. The magnet system is a crucial part of the PB2, since it is responsible for compensation of the weight of up to 100 g with a minimal amount of power loss and because it needs to be characterized with relative uncertainties in the sub ppm range. This article is dedicated to the design considerations for the magnet system which were done using an analytical and a numerical approach.

2:10 p.m.	D. Knopf, T. Wiedenhöfer, K. Bauer, F. Härtig (D-Braunschweig)

Dissemination of the « Planck-Kilogram »

Since 1889 an artefact defines the unit Kilogram in the International System of Units. In 2018 metrologists worldwide are awaiting the decision about a change to a new system of international units defined via fundamental constants. Even the kilogram will be defined by a natural quantum based constant, the Planck constant. The new kilogram will overcome the gap to the electrical units measured based on quantum effects like the Josephson effect and the quantum Hall effect. But for daily life macroscopic realisations of this quantum based unit will be needed. Up to now only the experiments providing data for the redefinition of the kilogram - the Kibble-Balance, the Avogadro-Sphere (as result of the X-ray crystal density (XRCD) experiment) and the Joule-Balance - are expected to allow macroscopic realisations with the necessary small uncertainties. But, can these tremendously expensive and highly sophisticated experiments be used in the sense of disseminating the kilogram?
After a short glance at the potential of the Kibble(Watt)-Balance the presentation will describe the strategy of the Physikalisch-Technische Bundesanstalt to use silicon spheres of different qualities for the dissemination of the quantum based kilogram to the macroscopic world. Aspects like the connection to the established system as an important aspect for acceptance, the usability of the developed tools and procedures for using such spheres as mass standards or the current state of activities to proof the expected excellent long term characteristics of silicon spheres in use will be presented.

2:30 p.m.	L. Günther, C. Rothleitner (D-Braunschweig), J. Schleichert (D-Ilmenau), F. Härtig (D-Braunschweig

The Virtual Weight

A virtual weight is a numerical representation of a physical mass weight, describing the metrological behavior under certain measurement conditions. Based on a Monte Carlo simulation, it considers all significant influence variables with their respective uncertainty distribution. For the virtual weight this includes the ambient conditions, the cleaning status, the form, and material properties of the weight. It distinguishes between random and systematic errors and can thus be used to correct a measurement result for the task-specific prevailing ambient conditions. The virtual weight is part of the so-called Planck-Balance, a self-calibrating precision balance for industrial applications, currently under development in a cooperation of the Physikalisch-Technische Bundesanstalt and the Technische Universität Ilmenau. Enhanced with calibration data from a dedicated weight, the virtual weight becomes the digital twin of this specific weight. A first implementation of a digital twin of a mass weight has been set up as a demonstrator.

2:50 – 3:10 p.m. Coffee break and Visits of Expositions

3:10 p.m.	N. Rogge, J. Schleichert (D-Ilmenau), C. Rothleitner (D-Braunschweig)

Investigations on motion deviations of an EMFC balance

This paper will present experiments to identify the angular misalignment and displacement of the coil movement of a commercial electromagnetic force compensated balance (EMFC) relative to the ideal trajectory. For this purpose the mechanical stability of measurement set-up and the environmental characteristics have to be taken into account. Considering the mass distribution of the moved coil carrier, that is not necessarily symmetric relative to the motion path of the coil carrier, the spring constants regarding torques applied to the coil carrier are important to evaluate the utilized balance. The investigations are performed with different excitation frequencies to evaluate the influence of the resonance behavior of the balance mechanics and the limitations it causes for the usability of the balance.
The measured deviations of the balance, planned to be used in the Planck balance set-up, depending on position and velocity of the coil will be shown and the effect of the observed deviations on the measurement uncertainty of the mass dissemination will be discussed.

3:30 p.m.	R. Oliveira (BR-Rio de Janeiro), H. Lepikson (BR-Salvador de Bahia), R. Theska (D-Ilmenau), T. Fröhlich (D-Ilmenau)

Evaluation of the Principle for Generating Reference Inertial Torques for the dynamic Calibration of Torque Transducers

The dynamic traceability of torque transducer is still under the research level in the international metrological scenario. The authors proposed a calibration system using the inertial torque, generated from angular acceleration regimes and mass moments of inertia attached to the sensor. This paper presents the first phase of testing and characterizing the components of the proposed system, which is anterior to the metrology tests. The main objective is to check for the feasibility of these components working together in the assembly. The discussions around experimental results gave the orientation for formulating ideas and how was the preparation for second phase.

3:50 p.m.	N. Yan, M. Kühnel, S. Vasilyan, T. Fröhlich (D-Ilmenau)

Calibration of the torsion force measurement system for the Lorentz force velocimetry application

The in this paper described torsion force measurement system contributes to the Lorentz force velocimetry application, where the horizontal force in combination with dead load of 1 kg is measured. The theoretically calculated stiffness of the system is 0.5 N/m, undamped nature frequency is 0.06 Hz and it is expected to achieve the force resolution of 0.5 nN. Initially the electrical voltage as the output signal of the photoelectrical position sensor is converted into angle with an autocollimator system. Then the output signal of the position sensor is calibrated into force with the help of a known tilt force generated by tilt angle and a normal mass piece, the convert factors for the two positon sensors are 37.1038 μN/V and 38.7247 μN/V. A standard deviation of 5.5 nN over one hour has also been achieved and the linear working range of the system is nearly $\pm$ 40 μN.

4:10 p.m.	R. R. Marangoni, J. Schleichert, I. Rahnenberg (D-Ilmenau), F. Hilbrunner (D-Göttingen), T. Fröhlich (D-Ilmenau)

A self-calibrating multicomponent force/torque measuring system

A multi-component self-calibrating force and torque sensor is presented. In this system, the principle of a Kibble balance is adapted for the traceable force and torque measurement in three orthogonal directions. The system has two operating modes: the velocity mode and the force/torque sensing mode. In the velocity mode, the calibration of the sensor is performed, while in the force/torque sensing mode, forces and torques are measured by using the principle of the electromagnetic force compensation. Details about the system are provided, with the main components of the sensor and a description of the operational procedure. A prototype of the system is currently being implemented for measuring forces and torques in a range of ±2 N and ±0,1 Nm respectively. A maximal relative expanded measurement uncertainty (k=2) of 10·10-5 is expected for the force and torque measurements.

End of Session

Session 1.2 Measurement and Sensor Technology

Time: Tuesday, 12.09.2017
Location: Humboldtbau | Lecture Room 211/212
Chairman: T. Fröhlich (D-Ilmenau)

1:30 p.m.	Y.-H. Tu (TW-Taoyuan), S.-P. Lin, W.-H. Lu, P. T. Lin (TW-Taipei)

A Novel Method for Measuring the Thermal Emissivity of Opaque Objects

1:50 p.m.	L. Quentin, R. Beermann, A. Pösch, E. Reithmeier, M. Kästner (D-Hannover)

Enhanced Measurement Routine for Optical 3D Geometry Measurement of Hot Specimen by Reduction of Ambient Pressure

Optical 3d geometry measurement is a vital part of the process control when manufacturing hybrid components. Within the Collaborative Research Centre (CRC) 1153 a production chain for high performance hybrid components is being developed. These so-called Tailored Forming workpieces are composed of two or more materials and processed without cooling down to save energy. For a 100% process control, they are meant to be inspected fast, in hot state and with high accuracy by fringe projection.

An inhomogeneous refractive index field is developing around hot objects due to the change of density in air. Light traversing aforementioned field is deflected towards denser air layers. The assumption of rectilinear light propagation is violated. Therefore, optical measurements based on the triangulation principle are less accurate. The resulting accuracy loss is subject to this paper. The positive impact of a pressure reduction on the achievable measurement accuracy has been predicted by previous simulations.

For this paper, experiments have been conducted using a vacuum chamber and a self-developed fringe projection system in order to validate the simulations. The obtained measurements results are discussed and interpreted according to analytical deflection model.

2:10 p.m.	L. Lippmann, K. Irrgang (D-Martinroda), M. Hohmann, M. Pufke (D-Ilmenau)

High accuracy temperature measurement and monitoring of flow parameters using a multifunctional temperature probe

This publication describes the concept of a functionally integrated measuring instrument realized as a multifunctional temperature probe. This tool is capable to do temperature measurement in a highly accurate manner and a simultaneous determination of further process parameters. The high precise temperature measurement is accomplished by diverse temperature sensors inside one measuring instrument and an electronic circuit whereby the physically caused measurement deviation is corrected calculatedly. The geometric parameters of the sensor elements in combination with their respective signals allow the determination of certain stream properties. To verify the functionality of the engineered measuring tools a testing environment to elaborately examine the engineered prototypes was created. The precise test parameters are a setting of a turbulent pipe flow with a velocity between 1m/s and 30 m/s and a temperature range between room temperature and 200°C.

Prototypes of the multifunctional temperature probe built by tmg are tested in the specifically developed test equipment. The result of this project is a temperature probe which contains up to four temperature sensors and a mathematical model which is included in an electronic circuit. In addition to a high precise temperature measurement an independent self-control and the monitoring of divers process parameters is realised by one single measuring instrument.
2:50 – 3:10 p.m. Coffee break and Visits of Expositions
End of Session
4:00 p.m. Start Excursion to Arnstadt | Start Mensa (Dining Hall)

B. Stadnyk (UA-Lviv), T. Fröhlich (D-Ilmenau), Y. Khoma (UA-Lviv), V. Herasymenko (UA-Lviv), O. Chaban (UA-Lviv)

Impedance Analyser Error Correction Using Artificial Neural Networks

The aim of current study is to investigate the possibility of application of artificial neural networks for error correction in impedance measurements. In the paper multi-layer perceptron was applied to reduce resistance and reactance measurement errors. Input capacitance, output resistance and bandwidth of operational amplifier as well as raw measurement results were taken as network inputs. Corrected resistance and reactance values were returned as a network output. The accuracy of the method is compared with the values calculated with analytical formulas derived for equivalent circuit of the measurement converter. The consideration presented in the study focuses only on decreasing errors of the impedance/voltage conversion, neglecting errors being introduced by other measurement transformations i.e. phase-detection and analog-to-digital conversion.

Y. Bobalo, M. Mykyychuk, S. Yatsyshyn, B. Stadnyk, (UA-Lviv)

I-T Converting Element of Quantum Temperature Standard

Possibility of researching the most contemporary measure of temperature on the basis of fundamental physical constants with involvement of the Standard of Electrical Resistance on the basis of Inverse of Conductance Quantum as well as the Standard of Voltage based on the Josephson junctions array is considered. Its realization depends mainly on the operation of unique electronic device, the work of which forms the basis of the transformation of pulses of electrical voltage into the calibrated jumps of temperature. On the one hand it should be super miniature and pass currents of magnitude of order 1 nA, and on the other hand it should perform the functions of active temperature-sensitive element.

R. Schüler, I. Rahneberg, H. Mammen, E. Mengs, M. Schalles, T. Fröhlich (D-Ilmenau)

PT-100 air temperature sensor with enhanced dynamic properties

To enhance the accuracy and dynamic of air temperature measurement especially for applications in interferometry and machine calibration a new high dynamic temperature sensor has been developed. The limiting factor for laser interferometry accuracy in air is the exact knowledge of the air refractive index which strongly depends on the air temperature. Another factor is the upcoming wish to mount temperature sensors on moving parts. To follow temperature changes with moving sensors especially in non climatized rooms is a very challenging task for the sensor dynamic.

The new developed sensor is based on Pt-wire on ceramic substrate. Due to it's symmetrical construction there is no directionality in the dynamical properties. The surface is passivated so the sensor can be calibrated in a wet media. To enhance the accuracy the sensor is usually equipped with an integrated measurement electronics (wired and wireless) which allows the calibration of the whole measurement chain at once. A climate station to use up to 15 wired and 15 additional wireless sensors is also available. The following performance has been reached: T63=6.3s, measurement interval: >0.9s, resolution 0.1mK (wired) or 10mK (wireless), accuracy: +-50mK (depending on calibration).
Besides the interferometry the new developed high dynamic temperature sensor has many fields of application, for instance the evaluation of the quality of climatized rooms and the surveillance of measurement chambers or climate chambers.

K. Höpping, K. Augsburg, F. Büchner (D-Ilmenau)

Extending the HSRI tyre model for large inflation pressure changes

The development of a highly dynamic Tyre Pressure Control System (TPCS) as a driver assistance system can reduce the conflict of minimal rolling resistance and maximal traction. To study the influence of the tyre inflation pressure on longitudinal tyre characteristics under laboratory conditions, an experimental sensitivity analysis is performed using a multivalent usable Corner Module Test Rig (CMTR) developed by the Automotive Engineering Group at TU Ilmenau. The test rig is designed to analyse suspension system and tyre characteristics on a roller of the recently installed 4 chassis roller dynamometer. Camber angle, toe angle and wheel load can be adjusted continuously. In addition, it is possible to control the temperature of the test environment between -20°C and +45°C. The results of the experimental study, that covers a wide range of different wheel loads and inflation pressures for three different tyre variations, show a significant influence of the inflation pressure on longitudinal tyre characteristics. To simulate the influence of a TPCS on vehicle dynamics with a numerical simulation tool, it is essential to describe the influence of the inflation pressure on tyre characteristics correctly with a tyre simulation model. Consequently, the well-known physically based HSRI tyre model is extended for large inflation pressure changes. The extended HSRI tyre model shows a good model accuracy to represent the tyre inflation pressure dependent tyre characteristics.

O. Oleskiv (UA-Lviv), T. Fröhlich (D-Ilmenau), I. Mykytyn (UA-Lviv)

Problems of Metrological Verification of Software for modern Measuring Instruments

During the last 5 years, the department of information and measurement technology, National University "Lviv Polytechnic", team of scientists is engaged in problems of the metrological verification (MV) of modern measuring instruments (MI) especially of their software. In this article the considerations concerning the necessity of metrological verification of measuring instruments software are presented. The purpose of work is an acquaintance of the scientific world with the main tendencies in the development of metrology of modern

measuring instruments and justification of the need for metrological verification of measuring instruments software. The goal of this issue is an acquaintance of the scientific world with the main tendencies in the development of metrology of modern measuring instrument and justification of the need for metrological verification of measuring instruments software. Another debatable question is a necessity of MV of MI software on the stage of exploitation. Since the software for MI does not change during exploitation, then his verification should be done only at the design and development stage. However, today the theoretical and practical foundations of CPS are being created (except for emergencies). Depending on the put task cyber-physical systems (CPS) will form an original robotic computer system. For this purpose, components of the CPS and related software of general purpose and software that will be used for MI of robotic equipment will be involved from the existing park. In order for CPS to perform varied tasks, they must use flexible software, which will mainly be obtained through cloud-based technologies. That is, with the statement of the new task will be used other MI software. And it suggests an idea that in such case software, which will be calculate the result of the measurement using a certain algorithm, must undergo MV. This will guarantee the correct work of the robots involved in the CPS, and thus will ensure the safety of human life. In addition there is another question: after what criterions the CPS choose software, and also for the involved MI. Which software parameter should characterize it so that the CPS correctly chooses the software that is optimal for the task. And there is a simple answer on this question: for MI software, which is used in the CPS, such characteristic is error of software computing the measurement result. That is, the software will be characterized by not qualitative, but a quantitative characteristic, which enables quickly to compare variants of the same type software and choose the optimal, in obedience to the put task of measurement. Certainly, the producers of MI software must conduct MV and ascribe declared metrological characteristics of software. On the other hand, the CPS must conduct a MV of software and check whether the received metrological characteristics are in accordance with the declared. If the result is positive, then the software can be used. Otherwise, another software is searched. Recently considering in science, the MV of MI software is used extremely rarely. In the nearest future, due to implementation of CPS in production and services, the issue of MV of MI software will need to be resolved and regulated by law.

Session 1.3 Precision Engineering and Optics

Time: Wednesday, 13.09.2017
Location: Humboldtbau | Lecture Room 012
Chairman: R. Theska (D Ilmenau)

9:00 a.m.	M. Darnieder, R. Theska, T. Fröhlich, M. Pabst, R. Wenig (D-Ilmenau), F. Hilbrunner (D-Göttingen),

Design of high-precision weighing cells based on static analysis

The presented research activity belongs to the field of precision mass metrology. Here, mass comparators are an indispensable element of the dissemination chain of the SI-unit kilogram - now and subsequent to the upcoming redefinition of the unit of mass. The mechanical system of present mass comparators consists of monolithically manufactured compliant mechanism with flexure hinges. The objective of a further development of these highly developed systems requires a significant reduction of its susceptibility to external disturbances. Amongst others, these are long-periodic ground vibrations and quasi-static ground tilt. The modeling of the latter, along with the introduction of a novel adjustment concept, is treated in the present study. The monolithic structure is approximated by a rigid body model. Established adjustment concepts for the stiffness characteristic and the sensitivity to quasi-static ground tilt are included. They are complemented by the introduction of further adjustment masses. Based on this concept, an optimal design for the weighing cell is determined. The design is further refined using a geometric non-linear finite element model. By variation of the adjustment parameters in the finite element model, stiffness and tilt sensitivity are reduced by five orders of magnitude compared to the unadjusted weighing cell.

9:20 a.m.	B.-A. Behrens, R. Krimm, Q. T. Nguyen (D-Hannover)

Motorized Measurement Device for automatic Registration of Cutting Edges

Sheet metal products can be found in almost all household-, electrical appliances, vehicles and industrial machines. One of the widely spread methods of sheet metal processing is the shearing process which separates large sheets into smaller sections (stampings) for subsequent operations. Cutting edges of stampings are substantial for the evaluation of the product quality. For this purpose the significant parameters of cutting edges such as rollover, burnish, fracture and burr are standardized in VDI norm 2906. Currently, the most popular methods of evaluation of cutting edges are metallography, confocal microscopy and tactile measuring systems, which are still time-consuming and cost-intensive, since the stamped parts need to be analyzed by qualified personnel. This work is based on objectives aimed at developing a motorized measurement device, which registry edge profiles automatically by means of optical sensors and calculate parameters of cutting edges by means of an algorithm. Therefore no specific knowledges of user are required for the evaluation.

9:40 a.m.	L. Zhifeng, X. Pengfei, F. Kuangchao (CN-Dalian)

Analysis of Angular Indexing Error Caused by Coaxial Deviation of Double Centres in Machine

10:00 a.m.	Ch. Hahm, R. Theska, D. Raab (D-Ilmenau), A. Fehringer (D-Asslar), A. Kästner (D-Deggendorf)

Qualification of silane coatings for the strength enhancement of concrete parts

In former own publications it was shown, that high precision concrete parts are a reliable alternative to natural stone for machine base frames. Concrete is a promising material for the whole machine structure. In contrast to base frames, moving parts need to have a lightweight design requiring a high specific stiffness. To guarantee reliability at the same level as steel or aluminum light weight parts, the endurance strength of concrete parts has to be improved significantly.

Reinforcement by implementation of steel or carbon fibers is not applicable since it comes with thermal inhomogeneity. As an alternative, reinforcement can also be derived by functional coating. The application of a tailor made sol gel coating with enhanced tensile strength like organo functional silane is a promising approach.

In this contribution fundamental effect mechanisms and the coherences to the endurance strength are shown. An experimental method for the verification of the influence of the coating to the endurance strength is presented. The presentation is focused on the necessary experimental setups for the determination of the mechanical properties and the influences on the coated parts.

The efficiency of the sol gel application on concrete parts to achieve stiffness improvement has been proven. Since the distributions of the tested mechanical parameters are in the magnitude of the test arrangement uncertainty, a statistical reliable prediction of the endurance strength enhancement can be done.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions

10:40 a.m.	H. Scheibe, C. Schindler (D-Jena), R. Theska (D-Ilmenau)

Technologies for Cost-effective Manufacturing of Precision Aspheres and Freeforms

Optical technologies are considered to be a major economic growth driver of the 21st century. Prior advances in the field of optical technologies were mainly focused on mounting technologies to attain tighter specifications. By now, these can be met safely such that the emphasis of nowadays developments is piled on cost-effective manufacturing technologies for precision aspheres and freeforms. These are producible in terms of form deviations, roughness, homogeneity and stress birefringence, though cost and time consuming production processes preclude their use in cost-sensitive products. The demand for a miniaturization and integration of additional functionalities is restricted by the exclusive use of spherical optics. Today's mechanical designs are already close to that border. However, the use of aspherical optics enables a reduction of the total number of optical elements which causes major benefits in terms of required installation space, weight, mechanical design effort and system complexity. Beyond that, the use of freeform optics instead of spheres / aspheres promises an even greater reduction and enables new optical functionalities.

The aim of this paper is to present the latest research on a full aperture polishing technology for precision aspheres and to gain insight into alternative – mainly beam based – process chains for precision freeforms. Both technologies promise a considerable manufacturing cost cutback by reducing or skipping the use of bonnet polishing.

11:00 a.m.	N. K. Pavlycheva, R. R. Akhmetgaleeva, E. R. Muslimov (RU-Kazan)

Optical scheme of small-size curved detector spectrofluorometer

We present two versions of a compact spectrograph optical scheme based on aberration-corrected concave holographic grating. It is shown that performance of a widely-known flat-field spectrograph scheme can be significantly improved by means of use of a curved detector and introduction of an additional condition of coma correction.The spectrograph provides spectral resolution up to 0.23 nm over an extended working range of 250-900 nm and can be used for fluorescence analysis of waste water.

The computation results clearly show that combination of a holographic diffraction grating and a curved detector allows to obtain a drastic improvement of spectral resolution with medium-to-high apertures. Thus it becomes possible to build a compact spectrograph with enhanced sensitivity in a broad spectral range, which can be of high interest for fluorescence analysis of water samples.

11:20 a.m.	K. Hayashi, B. Chu, Z. Zhao, M. Michihata, K. Takamasu, S. Takahashi (JP-Tokyo)

Evaluation strategy of spheroidal distortion for micro-sphere based on Whispering Gallery Mode resonance

The demand for measuring the diameter of the spherical object, which is used for the CMM (Coordinate Measuring Machine) stylus, for example, is now rising and its measurement error is desired to be less than several 10 nm for the spherical object whose size is around 100 μm. To achieve this, the measurement method based on WGM (Whispering Gallery Mode) resonance is remarkable. However, as long as we rely on this method, the model of the object must be a perfect sphere, and this assumption should not always be true. Practically, a measured sphere has the rotational symmetry so that it suffices to evaluate the spheroidal distortion for knowing macro-distortion. According to this motivation, we proposed the new measurement method to appreciate the degree of distortion for the object based on WGM resonance. Degeneracy for azimuthal direction disappears if the object distorted spheroidal-like. Based on such a characteristic of spheroidal particle, we can evaluate the degree of spheroidal distortion (in this case, ratio of the longer axis radius and the shorter one).

Since WGM resonant wavelength can be approximated as a linear function of spheroidal distortion, measuring the interval between the resonant wavelengths for different azimuthal mode number enable us to evaluate the distortion. Practical restriction comprising resolution of the spectrometer and specification of mode numbers was also discussed.

11:40 a.m.	M. Michihata, B. Chu, Z. Zheng, K. Hayashi, K. Takamasu, S. Takahashi (JP-Tokyo)

Accuracy improvement in diameter measurement of micro-sphere based on Whispering Gallery Mode

We have been proposed the new method to measure a dimeter of a micro-sphere on a basis of whispering gallery mode resonance. Resonant wavelengths and mode numbers are necessary quantities to calculate the diameter. In this paper, we proposed and discussed the method to determine the radial mode number of WGMs. Experiments showed the well agreed diameters from various resonant wavelengths, which implies that the radial mode numbers can be successfully estimated by means of the proposed method.

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions

1:30 p.m. – 4:30 p.m. Ehrenkolloquium in memoriam an Prof. E. Kallenbach

Session 1.3 Precision Engineering and Optics

Time: Wednesday, 13.09.2017
Location: Humboldtbau | Lecture Room 012
Chairman: St. Sinzinger (D-Ilmenau)

1:30 p.m.	P. Gräser, S. Linß, L. Zentner, R. Theska (D-Ilmenau)

On the influence of the flexure hinge orientation in planar compliant mechanisms for ultra-precision applications

This paper presents the investigation of specific geometric parameters of planar compliant mechanisms with flexure hinges. The main focus is on the geometrical orientation of the flexure hinges and the form of the link connections between them. The synthesis of the compliant mechanism using a selected rigid-body model by replacing the hinges and the design process of the mechanism are shown. Therefore different parameters are selected and FEM simulations are done to investigate the motion behaviour. After the simulation process a special test bench is designed to measure the path of motion of prototypes and to verify the simulation results.

1:50 p.m.	V. Musalimov, K. Nuzhdin (RU-Sankt Petersburg)

Bifurcation components of sliding friction

Problems of friction and wear investigations are very important in precision engineering area. This work is focused on study of surface structure of tribological pairs. The main objective is a qualitative and quantitative explanation of the reasons of friction in the context of analyzing bifurcation processes which are related to buckling failure of individual elements of microcontacts. There was shown method of structure modeling of surface roughness by using an elastic element. The proposed method demonstrates dependences between the dynamic characteristics of the tribological interaction and external structural parameters of the friction surfaces. In addition, this approach makes it possible to evaluate the surface characteristics of tribological pairs, for example, asperity.

2:10 p.m.	M. Hillenbrand, W. Singer, H. Münz, N. Kerwien (D-Jena)

See-Through Near to Eye Displays: Challenges and Solution Paths

Many consider see-through near to eye displays the successors to the smartphone and envision a multitude of mixed reality and augmented reality applications. The ideal optical imaging system for a see-through near to eye display combines a large field of view ($\geq$ 100°) with a large pupil ($\approx$ 20 mm) and is both lightweight and unobtrusive.
In our contribution we first give an overview of challenges related to the design of see-through near to eye displays. Starting from the requirements of the human visual system, we then focus on two main performance parameters: field of view and aperture. These two parameters can be combined in a single parameter, the etendue. We show that the etendue of a see-through near to eye display is comparable to the etendue of lithography lenses and full frame camera lenses. To deliver the same etendue with a much lighter and more compact optical system is one of the main challenges of see-through near to eye displays. We discuss two possible solution paths: to increase the etendue close to the eye and to use foveated imaging concepts.

2:30 p.m.	M. Heusinger, M. Banasch, U.-D. Zeitner, E.-B. Kley (D-Jena)

High precision electron-beam-lithography for optical high performance applications

In this manuscript we present a method that allows a precise calibration of the stitching of special subareas that occur in electron beam lithography in order to fabricate large area micro-optical elements. The method is based on the evaluation of angle resolved stray light measurements of special test gratings. In particular, the qualitative and quantitative appearance of deterministic stray light peaks, so called Rowland ghosts, are related to the modality and the strength of the alignment error. It is shown that the origin of the Rowland ghosts must be purely systematic and, thus, that the Rowland ghosts can be used in order to optimize the stitching process and the alignment accuracy, respectively.
Based on this findings, an optimization is exemplarily demonstrated on a current high performance spectrometer grating. The Rowland ghosts in such a grating typically have a strength of less than 10-4 compared to the useful diffraction order. As a result, the calibration state of the e-beam-writer was found to have a deterministic alignment error of 5 nm, which was reduced to a minimum error in the range of 1 nm. This corresponds to a reduction of the Rowland ghosts of almost 2 orders of magnitude.

2:50 – 3:10 p.m. Coffee break and Visits of Expositions

3:10 p.m.	C. Stock, Th. Siefke, U. Zeitner, E.-B. Kley (D-Jena)

Nano-optical quarter-wave plates for applications in the visible wavelength regime: fabrication, tolerances and in-situ process control

The controlling of the polarization state of light is required for various photonic applications, e.g. for biomedical imaging, lithography, microscopy or ellipsometry. Major advantages of micro- and nanostructures for polarization control are realization of elements for spectral bands, where no alternatives exist (e.g. polarizers in the UV wavelength range) and better integration with optical elements or sensors. Nano-optical polarizers and wave plates can be used to fully manipulate and convert the state of polarization. The fabrication of sub-wavelength grating quarter-wave plates for applications in the visible and near infrared wavelength regime is challenging. In this work major grating structure deviations, namely grating ridge tilt, chamfers on top of the ridges, grating displacement and their influence on phase retardation are investigated. Basing on this we present theoretical investigations and experimental results for an in-situ process control. Thereby, the impact of structure deviations can be compensated and a fine tuning of the phase retardation becomes feasible. We demonstrate this approach by fabrication of a wave plate for 532nm wavelength. This work is the foundation for future development of such an in-situ process control.

3:30 p.m.	M. Bichra, T. Meinecke, L. Müller, P. Fesser, M. Hoffmann, St. Sinzinger (D-Ilmenau)

Innovative freeform measurement method using two dimensional binary diffractive grating based on nanostructured silicon

An innovative metrological method for freeform characterization in transmission as well as in reflection has been developed. The approach is based on diffraction theory and Fourier analysis with modified angular spectrum propagator. We analyze the propagation of a wavefront behind a two-dimensional cross grating and derive a universal method to measure the phase gradient directly from the recorded intensity distribution. This method works for arbitrary distances behind the grating. To prevent unwanted reflection while measuring in reflection and in transmission we use a two dimensional cross grating based on nanostructured black silicon. Our new formulation has been tested successfully through simulations. The wavefront generated by a freeform surface was measured with the new method. The experimental results are verified with a commercial Shack- Hartmann wavefront sensor.

3:50 p.m.	P. Beloivan, S. Latyev (RU-Sankt Petersburg), R. Theska (D-Ilmenau)

Features of assembly and adjustment of lens objectives

To reduce the impact of mating clearances and of other deviations of the parts on alignment of lenses relative to the reference axis of their cells, the use of reference surfaces at cells and lenses or the method of alignment of lenses in the process are common. Clearances result in a shift to the reference axis of the optical system. The amount of misalignments caused by clearances of lens components in barrel type optical systems considerably depends on assembly conditions. For vertical assembly the shifts of components may reach half the maximum clearances. For horizontal assembly lens components shift under action of gravity to the subjacent feature of the cylindrical bore of the body, thus becoming the real base instead of the symmetry axis of the body. Comparison of misalignments for the horizontal and vertical assembly methods show that horizontal assembly allows vast reduction of the impact induced by clearances on lens alignment. Residual misalignments of lens components are usually too large to accomplish satisfactory image quality. Further adjustment is needed, that turns out to be difficult especially if there are equally high requirements given at both the center and the rim of the image. Analysis of impact given by misalignment of operating surfaces of lenses on aberration allows to find an independent way for adjustment of the image quality at the center and the rim of the image.

End of Session

Session 1.4 Optics for Illumination, Imaging and Metrology

Time: Thursday, 14.09.2017
Location: Humboldtbau | Lecture Room 010
Chairman: St. Sinzinger (D-Ilmenau)

9:00 a.m.	X. Cao, St. Sinzinger (D-Ilmenau)

Removal of optical aberrations caused by illumination system in Fourier ptychography

The Fourier ptychographic microscopy (FPM) algorithm provides a method for reconstructing a high resolution image by stitching together the Fourier spectra of a number of low resolution intensity images, which are taken under various inclined illumination angles. However, the quality of the reconstructed image can be distorted by the optical aberrations of the illumination system. In this paper we investigate the influence of the optical aberrations on the reconstructed intensity images by using the FPM algorithm and discuss whether is it possible to remove the optical aberrations of the illumination system.

9:20 a.m.	H. Lietz, J. Eberhardt (D-Weingarten)

Introduction to Fourier Ptychographic Imaging for 3D ToF cameras

Photonic mixing device (PMD) cameras are suitable for fast and robust three-dimensional image acquisition. They use an inherent amplitude modulated signal to measure running time of light (ToF) and calculate its travel distance from camera to object scene. Currently, development focusses on miniaturization of such cameras for integration in mobile devices like smartphones and tablets. Advantageously, they are cost efficient, small in size and have low energy consumption. However, there is a great limitation in low lateral and depth resolution. State of the art, lateral sensor resolution is about 64 x 16 pixels (Ifm O3M151) for outdoor systems and reaches a maximum of 512 x 484 pixels (Microsoft Kinect v2) for indoor systems, which is even less than VGA standard from 1987. Depth resolution is in sub-cm range, mainly depending on measurement distance.
Fourier ptychographic imaging (FPI) extends Fourier domain synthetically by capturing several frequency domain shifted images. In addition to spatial resolution enhancement, FPI allows recovery of a complex light field's phase information. With this work we want to introduce FPI for 3D PMD cameras. It discusses what has to be considered for an experimental setup and why we recommend an aperture-scanning setup with reflection mode illumination. Simulations promise a significant increase in lateral resolution and it is shown, that lateral resolution enhancement via FPI follows an asymptotic progression.

9:40 a.m.	S.-T. Lin, T.-X. Hung, S.-W. Shi (TW-Taipei)

3-D microscope using broad-band source interference pattern

10:00 a.m.	D. Karthaus, O. Sandfuchs (D-Lippstadt), St. Sinzinger (D-Ilmenau)

Transmission Volume Holograms for LED Illumination

The application of transmission holograms in automotive headlamp systems is a possible new field of application for holographic elements. However, it requires the adaptation of holograms to light-emitting diodes (LEDs) as reconstruction light sources. This includes the consideration of the reconstruction wavefront shape. Therefore, computer-generated holograms (CGHs) are designed for different LED wavefront approximations and recorded in a photopolymer. Within experiments, the performance of the optimization is analyzed. For reconstruction, an automotive-certified LED is used and the reconstructed image is recorded. The correlation of the ideal and the real reconstructed image is used as indicator for a successful adaptation within the design process. It is shown that there are clear differences regarding the improvement of the correlation between the considered wavefront approximations. The best results are achieved with a wavefront, determined from an interferometric measurement, and with a wavefront with Lambertian characteristic.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions

10:40 a.m.	C. Menke (D-Oberkochen)

Optical Design with Orthogonal Freeform Representations

11:00 a.m.	A. Hofmann (D-München)

Optical Design for Manufactoring for Freeform Optics

11:20 a.m.	K. Bredemeier (D-Ilmenau)

Photometric data for the development of lighting components

The availability of accurate photometric data is crucial for the development of lighting technology components. Especially in the course of the displacement of the classical lamps by solid-state lighting (SSL) technologies and the resulting increased range of lighting applications, the requirements for these measurement data have increased. Here, optical simulation programs based on ray tracing algorithms (Computer-Aided Lighting – CAL) open up new development processes.

State-of-the-art is the use of ray files measured by camera-based near-field goniophotometers. Some of those systems also offer measurements of the luminous intensity distribution, luminous flux and goniospectrometric data in conformity with IES LM-79-08, EN 13032-4 and CIE S 025, and can thus also take over the classical measurement tasks of far-field goniophotometers.

11:40 a.m.	N. Fernkorn (D-Goslar)

Challenges for lighting manufacturers at optical design for luminaires

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions
12:00 noon – 1:30 p.m. Poster Session | Foyer Humboldtbau

Poster Session 1.4 Optics for Illumination, Imaging and Metrology
Time: Thursday, 14.09.2017, 12:00 noon – 1:30 p.m.
Location: Foyer Humboldtbau

P. B. Costa, G. F. da Silva, W. S. Barros (BR-Rio de Janeiro)

Flank wear measurement: a procedure proposal using computer vision techniques

This study presents a developed methodology for evaluating wearing helical drills using a computer vision system. The work takes part in a project for the production of ecofriendly cutting fluids. One of the form taken to analyze the fluid efficiency was determining the tool's wear during the machining. For the tests, high speed steel drills with 3 mm and 7 mm diameter were used. The drills were photographed before and after the drilling of 50 holes in a 1020 steel plate using the ecofriendly and the normal cutting fluids. The images were processed and analyzed to measure the flank wear. In this paper the methodology for acquisition, process and image analyze for flank wearing measurement will be shown. Besides, it will also present a different parameter based on the wearing area for low wear values.

P. B. Costa, W. Barros (BR-Rio de Janeiro)

Accuracy study of an adapted optical CMM on two-dimensional artifact calibration

S.-T. Lin, T.-X. Hung (TW-Taipei)

Shearing interference microscopes using Savart prism as the shear plate

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Topic 2

Industry 4.0 and Digitalisation in Mechanical Engineering

Session 2.1 | Production Technology, Machinery, Digitalisation – State of the Art and Perspectives
Session 2.2 | Image Processing Based Process and Quality Control
Session 2.3 | Plastics Technology – Interfaces in Materials, Processing and Manufacturing

Session 2.1 Production Technology, Machinery, Digitalisation – State of the Art and Perspectives

Time: Tuesday, 12.09.2017

Location: Humboldtbau | Lecture Room 202

Chairmen: J. P. Bergmann, J. Hildebrand (D-Ilmenau)

1:30 p.m.	K. Bothe, A. Winkler, L. Goldhahn (D-Mittweida)

Development of a robot-human-interface using an RGBD camera

Against the backdrop of global economic development, industrial assembly in Germany is in a state of change, prompted by the country?s high-wage business environment. This article describes the need for new technologies to the increase flexibility and security regarding human-robot cooperation. Furthermore, a possible model for managing this transition is described on detail, involving the use of an RGBD camera from Microsoft. The camera does not meet safety regulations, which is why the camera is only used under laboratory conditions for the purpose of this research. With this camera, it should be possible to detect state and position changes of people in a human-robot workstation and consequently adapt the movements of the robot. Overall, the essential aim of this paper is to suggest ways to increase economic efficiency within assembly processes along with increasing security.

1:50 p.m.	I. Koene, R. Viitala, P. Kuosmanen (FI-Aalto)

Vibration analysis of a large rotor over industrial internet

Excess rotor vibration decreases production quality and causes unscheduled maintenance breaks in the manufacturing industry utilizing rotating machinery in production. Measuring and monitoring the rotor vibration levels in production conditions provides added value through decreased maintenance costs and quality variations. E.g., paper and metal manufacturing are fields where the rotor running accuracy affects directly to the quality of the final product. In few production machines, critical components are equipped with a modern wired condition monitoring system to acquire vibration signals from the bearing housings during operation. However, upgrading a running production machine with this kind of system is expensive and requires a maintenance brake.

In the present study, a low-cost MEMS accelerometer sensor and wireless data transmitter were attached to a bearing housing of a large rotor. Measurement series was conducted to determine the subcritical vibration spectrum and the results were verified against a laboratory vibration measurement instrument. The vibration was measured during a rotor acceleration mimicking a production ramp-up.

2:10 p.m.	M. Reimche, J. P. Bergmann (D-Ilmenau)

Single item production within collaborative networks

Manufacturing in collaborative networks is an attractive strategy to cope with volatile customer demand. Not only high volume but also single item manufacturers have to deal with this challenge. Similar to manufacturers of standard products, single item manufacturers have to assess feasibility timely due to desired delivery day and estimate costs.

However, single item manufacturers do not have reliable data regarding process time to schedule the production and rate needed and unused capacity in order to collaborate in this type of networks. To simplify the production planning and cost calculating process, this research analyzes the application of a type representative method in collaborative networks of single item manufacturers. Using the example of a product which is manufactured in three steps, the application of the method is presented.
This method combines all characteristics of already manufactured products including their impacts on the process. The authors also suggest the determination of a factor f, which describes features of enterprises in collaborative networks and helps to improve the precision of required process time of the network. In addition, this leads to a more accurate calculation of the costs. Following researches will design a type representative based on concrete product data. This data will be collected by a medium sized enterprise within a collaborative network. Afterwards, an analysis of the deviation of the estimated and actual data is carried out.

2:30 p.m.	A. Laschkow, A. Lauffs (D-Hamburg), W. L. Weingaertner, M. Pereira, J. Gutjahr, A. Pereira (BR-Florianópolis)

Wire- and powder laser cladding of Inconel® 625

Due to the material properties and process applicability, laser cladding of Inconel® 625 is ought to have applications in the aerospace and deep-sea pipeline coating. This study background refers to the second application; thus, only single clad layers are presented. The focus is the comparison of layers made with wire and powder feeding laser cladding strategies. Processes suitability regarding application will be pondered over, while characterizing Inconel® 625 depositions and considering process characteristics. In a first step, the analysis considers a comparison between both cladding methods, operating within assumptions and a similar range of main parameters. After inferring from these results, the achieved knowledge is used to adjust settings on the second step, where both processes are optimized individually. Clad quality is evaluated regarding to geometry through optical microscopy, dilution percentage and chemical composition in different positions in the clad are analysed by EDS and substrate-to-clad hardness is measured.

2:50 – 3:10 p.m. Coffee break and Visits of Expositions

End of Session

4:00 p.m. Start Excursion to Arnstadt | Start Mensa (Dining Hall)

M. Preißler, M. Rosenberger, G. Notni (D-Ilmenau)

An Investigation for process capability in additive manufacturing

This work presents an investigation for process capability in additive manufacturing (AM). Fused Filament Fabrication (FFF) is the additive manufacturing method, which is based for this verification. The typically layer-upon-layer building method in FFF has special effects to the geometrical quality and is important for comprehending the challenges in the additive manufacturing. But the continuously increasing of manufacturing quality in AM methods has enlarges the applying from rapid prototyping to rapid manufacturing or even to rapid tooling. The reliable applying of AM methods in these areas needs an evaluation and validation for process stability and is part of this paper. The necessary tolerance specification for purposing the process capability is common in mechanical engineering and is considered in results.

The presented work provides a proof for additive manufacturing as industrial tooling. The manufactured results have adequate geometric precision for many cases in industry. Objects with only purpose for visualization the manufacturing accuracy are sufficient and objects with smaller structures and requirements for fitting might also manufactured. The further development of mechanical parts, drive trains and slicer algorithm will increase the accuracy in FFF manufacturing process. Currently sold FFF manufacturing machines are more capable then the used Ultimaker 2 extended+ and in future the process capability will getting higher.

Session 2.2 Image Processing Based Process and Quality Control

Time: Tuesday, 12.09.2017
Location: Humboldtbau | Lecture Room 010
Chairman: U. Krüger (D-Ilmenau)

9:00 a.m.	T. Scholz, M. Rosenberger, G. Notni (D-Ilmenau)

Using FPGA Block-RAM for fast white light interferometry

White light interferometry is a time consuming operation even on modern architectures. To overcome the high power consumption and size of traditional desktop computers an embedded approach containing the hybrid architecture Zynq will be presented. This architecture contains a dual core ARM and programmable logic provided by an FPGA.
FPGAs offer massively parallel logic gates and DSP-slices to parallelise certain tasks. Another important part is the internal memory BRAM. The presented approach aims to speedup calculation time of the ARM processor by utilization of this BRAM. It is well known that memory transfers consume a lot of time. To speed the transfers up, the bottlenecks have to be identified. In this paper it will be illustrated how to easily access an FPGA BRAM from a running operating system and the possible speedup will be analysed and estimated.

9:20 a.m.	A. Mitsiukhin (BY-Minsk)

Efficient description of the boundary of the object under observation

The efficient description of the object boundaries becomes a challenge when solving problems related to detection or search of certain objects on images as well as recognition or identification of them. The description of the boundaries of the objects of interest can be used when extracting the features in the process control problem. The efficiency of the description is achieved by presenting the boundary as a functional series of the coefficients of expansion in the basis of eigenfunctions of the covariance matrix. The compression process is based on the function of distribution of the 2-D dispersion of the Hotelling coefficients. Application of the dispersion criterion when describing the boundary of the object under investigation makes it possible to compress the data actually without losses. It is known that the spectral approach is important for the practice of compact description of data. This paper proposes the modification of this method, which takes into account the introduction of the input data sorting procedure into the processing algorithm for the purpose of more efficient selection and filtration of the dominant values of the Hotelling transform coefficients. The results of assessment of the efficiency of encoding the boundary image have been presented. At present, the considered method can be regarded as a practical computational procedure.

9:40 a.m.	S. Winkler, M. Rosenberger (D-Ilmenau), D. Höhne, C. Munkelt (D-Jena), C. Liu (D-Jena), G. Notni (D-Ilmenau, Jena)

3D Image Acquisition and Processing with high continuous Data Throughput for Human-Machine-Interaction and Adaptive Manufacturing

Many applications in industrial environment are able to detect structures in measurement volumes from macroscopic to microscopic range. One way to process the resulting image data and to calculate three-dimensional (3D) images is the use of active stereo vision tech

nology. In this context, one of the main challenges is to deal with the permanently increasing amount of data. This paper aims to describe methods for handling the required data throughput for 3D image acquisition in active stereo vision systems. Thus, the main focus is on implementing the steps of the image processing chain on re-configurable hardware. Among other things, this includes the pre-processing step with the correction of distortion and rectification of incoming image data. Therefore, the approach uses the offline pre-calculation of rectification maps. Furthermore, with the aid of the rectified maps, each image is directly rectified during the image acquisition. Afterwards, an FPGA and GPU-based approach is selected for optimal performance of stereo matching and 3D point calculation.

10:00 a.m.	O. Oliveira, H. Lepikson (BR-Bahia)

Influence of polinomial interpolation at tool path of REP-RAP FDM 3d printers systems

The recent growth in the concurrent engineering methods of additive manufacturing (AM) production has been a catalyst for developing new methods that are capable of meeting market demands. To produce parts from plastic filament represents a technique by Fused Deposition Modeling (FDM) widely applied by AM production. Notwithstanding all advantageous features of FDM AM technologies, an amount of disadvantageous conditions turn their usage mostly limited in a unprofessional enviroment. Several of that have direct influence on geometrical accuracy generating rough surface due to linear tool path interpolation normally used by traditional subtractive manufacture CAM systems. The objective of current research is analysing the influence of polinomial interpolation at geometric error of FDM AM systems, assembled based on information provided at opened sources platform. Consequently manual modifications were implemented at traditional's g-code printers aiming to modify standart linear g-code (G01) by modified polynomials g-codes, similarly to G05 used to implementing Cubic Splines at milling codes like Fanuc controllers.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions

10:40 a.m.	P.-G. Dittrich, M. Rosenberger (D-Ilmenau), D. Hofmann (D-Jena), G. Notni (D-Ilmenau)

Characterization and Correction of Multispectral Filter-On-Chip CMOS-Sensor-Systems for Spatial Resolved Spectral and Color Measurements

11:00 a.m.	Ch.-Ch. Ho (TW-Taipei)

On-line Monitoring of Gas Film Formation in Electrochemical Discharge Machining Processes based on Machine Vision

11:20 a.m.	M. Hänsel, M. Rosenberger, G. Notni (D-Ilmenau)

FPGA implementation of a multi-view stereo approach for depth estimation and image reconstruction for plenoptic cameras

In this paper a concept for an algorithm for depth estimation and image reconstruction for a plenoptic camera is presented. The algorithm follows a multi-view stereo approach and is intended for an FPGA-based Xilinx Zynq Ultrascale+ SoC platform to allow for real-time processing in an embedded environment. The micro-lens array separates a complete image in many micro-images. The micro-images are considered as individual cameras and the processing is calculated in a multi-view stereo approach. To accomplish an adequate frame rate and a reasonable resolution efficient processing steps and fixed-point integer calculation are chosen. The conceptual algorithm will be implemented and tried out in an experimental setting in 2019.

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions
12:00 noon – 1:30 p.m. Poster Session | Foyer Humboldtbau

Poster Session 2.2 Image Processing Based Process and Quality Control

Time: Tuesday, 12.09.2017, 12:00 noon – 1:30 p.m.
Location: Foyer Humboldtbau

T. Scholz, M. Rosenberger, G. Notni (D-Ilmenau)

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S. Winkler, M. Rosenberger (D-Ilmenau), D. Höhne, C. Munkelt (D-Jena), C. Liu (D-Jena), G. Notni (D-Ilmenau, Jena)

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M. Hänsel (D-Ilmenau)

FPGA implementation of a multi-view stereo approach for depth estimation and image reconstruction for plenoptic cameras

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Session 2.3 Plastics Technology – Interfaces in Materials, Processing and Manufacturing

Time: Tuesday, 12.09.2017
Location: Humboldtbau | Lecture Room 204
Chairman: M. Düngen (D-Ilmenau)

9:00 a.m.	N. Laufer, H. Hansmann, St. Ole, Ch. Boss (D-Wismar), M. Koch (D-Ilmenau)

Influence of flowability and MAH-content of maleated polyolefines on rheological and mechanical interaction effects of wood fillers in polyolefines

Natural fibre reinforced plastic have constantly high growth rates in the global market for years. Wood plastic composite (WPC) is an important representative of this class of materials. WPC consists of a thermoplastic matrix polymer which is filled with wood flour and additives that improve the processability and the product properties. In order to bond the polar wood fibres chemically to the nonpolar polymer matrix, coupling agents are used. The most important group of coupling agents for WPC are maleated polyolefins in which the backbone polymer as well as the maleic anhydride content (MAH-content) can be varied.
In this study, the influence of the flowability and the MAH-content of coupling agents on rheological and mechanical interaction effects of wood fillers in different WPC formulations have been investigated. It has been shown that the flow behaviour of WPC melts is highly influenced by interparticular interaction effects of the wood fillers. However, the results showed that both the MAH-content and the flowability of coupling agents are in terms of rheological interaction effects of negligible influence. Furthermore, it was found that mechanical interactions are significantly influenced by coupling agents. In this context, the flowability of the coupling agent is of greater importance than the MAH-content.

9:20 a.m.	St. Feustel, St. Caba, M. Koch (D-Ilmenau)

Processing and Quality of Continuous Fiber Reinforced Thermoplastic by Direct Extrusion

Thermoplastic sheets with continuous fabric or roving reinforcement offer the possibility of short cycle times. Conventional production solutions require double belt presses processing semi-manufactured plastic sheets or powders. An improvement of continuous fiber reinforced thermoplastic (CFRT) sheet production can be achieved through reduced energy consumption, increased output, improved impregnation and waste reduction. This work presents a high potential process applying a direct extrusion technology. It enables the impregnation and consolidation of woven textiles in an extrusion die with continuous throughput. A novel production line was developed and investigated for process capability. This extrusion process allows the production of CFRT sheet starting from thermoplastic granulate and woven textile in one single production line integrating plasticization, impregnation and sheet forming.

9:40 a.m.	A. Kutin, V. Musalimov, A. Polyakov (RUS-St.Petersburg)

Composite winding designing and control of the process of its making

Filament winding is a common method of manufacturing cylindrical composite products. It is the process of placing in strict geometric order on the surface of the threads or tapes, impregnated by composite resin. The winding material is usually carbon fiber or glass fiber

coated by a synthetic resin. The mandrel is removed, when the resin hardens. So the final product is formed. Linear speed of winding material and thread tension (tape) are maintained at a given level by special devices in the process of winding up. In spite of these facts it is impossible to stabilize the winding tension of the surface layer and to ensure for all reproduced products the same winding mode and the same winding density. Final products have differentiations in radius of winding along generator line of the cylindrical body and surface layer of the finished product has tuberosity. To address this shortcoming is offered the control system of the composite winding density. It should ensure the stabilization of the composite product's geometric parameters and its density.

10:00 a.m.	B. Neitzel, Ch. Fiebig, M. Koch (D-Ilmenau)

Influence of Fiber Undulation on the Mechanical Properties of Fiber Reinforced Plastics

The classical lamination theory is widely used for the calculation of the mechanical properties of reinforced plastics and stress distribution inside laminates. The resulting Young's moduli along the fiber direction are close to the achievable properties of unidirectional reinforced laminates. However in most applications woven fabrics are used that lower the stiffness of the composites. The influence of undulation and waviness of the fibers on the mechanical properties is yet to be explicitly specified. This article deals with the description of fiber undulation as well as the coherence between the geometry of fabrics and the achievable laminate properties. In order to get improved estimations for the Young's modulus, a new, easily applicable method is introduced to consider the undulation of fibers in the calculation process of the classical lamination theory (CLT). The results show that the given method leads to diminishing the error of the ordinary process.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions

10:40 a.m.	J. Geis, M. Koch, M. Bruchmüller (D-Ilmenau)

Influence of Fiber Length in Basalt Fiber Filled Thermoplastics on Mechanical Properties

This investigation focuses on fiber damage during processing and the effect of fiber length and fiber content of basalt fiber compounds on mechanical properties. A composite of basalt fibers (BaF) and Polypropylene (PP) is compounded with a twin-screw-extruder and specimens are fabricated via injection molding. Fiber contents and process parameters are varied in extrusion and injection molding processes. Fiber lengths and contents in specimens are determined and correlated with tensile strength, tensile modulus, impact strength and elongation at break. The investigation of the processes regarding fiber damage is necessary for determining achievable fiber length in moldings and resulting mechanical properties.

11:00 a.m.	R. Lima Stoeterau, N. Souza Silveira, M. S. F. de Lima (BR-Sao Paulo)

Comparative Analysis of Honed like and Dimple Laser-Structured Surfaces

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions
12:00 noon – 1:30 p.m. Poster Session | Foyer Humboldtbau

J. Rudloff, M. Wilhelm, M. Lang, P. Heidemeyer, M. Bastian (D-Würzburg)

Analysis and Simulation of the Melting Behavior of Polymer Materials in Co-Kneaders

The co-kneader is well known for its superior mixing performance and its exact temperature control capabilities. Therefore it is widely used in the polymer industry for the compounding of shear and temperature sensitive materials like PVC or high filled compounds. In contrast to the considerable amount of scientific work that deals with investigation, modeling or simulation of the process behavior of single and twin screw extruders there are only few publications about the co-kneader. Due to increased quality requirements and the trend for cost reduction by process optimization, this is increasingly becoming a problem for plant construction and processing companies.
To address this problem, experimental investigations of the melting behavior of polymer materials in the co-kneader had been conducted. In order to determine the melting degree along the extruder length a special barrel was used which can be opened in axial direction. Based on the experimental results, a theoretical consideration for co-kneaders that are operated as plastification extruders is proposed. The developed models are implemented into a simulation tool. A comparison between simulated results and experimental data shows a descent agreement.

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Topic 3

Mechatronics, Biomechatronics and Mechanism Technology

Session 3.1 | Mechatronics – Integrated Actuators
Session 3.2 | Biomechatronics
Session 3.3 | Mechanism Technology

Session 3.1 Mechatronics – Integrated Actuators

Time: Monday, 11.09.2017
Location: Humboldtbau | Lecture Room 129
Chairman: Th. Sattel (D-Ilmenau)

1:30 p.m.	V. Chigarev (BY-Minsk), K. Zimmermann, F. Becker (D-Ilmenau), V. Minchenya (BY-Minsk)

Theoretical and experimental investigations of micro robots based on piezoelectric triangular plates

The creation of mobile miniature robots is an advanced and promising branch of modern engineering. The most important issues in the design of such robots are the development of propulsion and energy systems. The use of miniature electromechanical systems in the technological world is growing rapidly. Considering new applications the piezoelectric drive is a practical base to create miniature robots which move on different surfaces and in different media. Due to the small dimensions and low energy supply the development of piezoelectric platforms for miniature robots in the form of spheres, cylinders, plates with support rods can effectively solve many theoretical and practical problems.
To study complex stress-strain states of plate-platforms for miniature robots methods of numerical analysis (finite element calculation) are used. This allows to obtain solutions of boundary value problems for plates with various shapes in conditions of a controlled resonance. This results can be compared with experimental data.

1:50 p.m.	R. Steinmeier (D-Brunswick), F. Becker, L. Günther (D-Ilmenau), V. Lysenko, V. Minchenya (BY-Minsk), I. Zeidis, K. Zimmermann (D-Ilmenau)

Approaches to the application of magnetic fluids in electromechanical drive systems

This paper shows the approach of applications of magnetic liquids in electromechanical drive systems. Magnetic fluids consist of colloidal ferromagnetic nanoparticles, a particle surfactant and carrier liquid. These fluids are divided into two groups called ferrofluids and magneto-rheological fluids (MRF). Both liquids are examined in two different kinds of electric motor prototypes. Following the ideas of Nethe [4], a ferrofluid is located in the air gap of an electrical drive. The influence on torque and especially heat transfer is shown by experiments. The system is also studied analytically as a classical Taylor-Couette-System. A second motor prototype is a novel and innovative magnetorheological assisted electrical machine. The construction and the functional principle are presented in this paper. In addition, some of first measurements are shown.

2:10 p.m.	S.-M. Kirsch, M. Schmidt, F. Welsch, N. Michaelis, A. Schütze, St. Seelecke (D-Saarbrücken)

Development of a Shape Memory based Air Conditioning System

The following contribution presents a new concept of an air conditioning device based on the elastocaloric cooling effect of shape memory alloys (SMA's). This technology provides an energy efficient and environment friendly alternative to conventional vapor compression

based cooling principles. Starting from the thermodynamic investigation of the elastocaloric cooling process, a continuous operating elastocaloric air cooling device is developed. The device enables an optimized thermodynamic process control under various operating conditions as well as large temperature spans. This work presents the design process of such a system starting from SMA based heat engines to a thermodynamically optimized design of an elastocaloric air conditioning device.

2:30 p.m.	S. Pech, H. Rathmann, R. Richter, T. Nagel, J. Lienig (D-Dresden)

Electromagnetic Actuator of a Gentle Pump Mechanism for Blood Transport

The maximum operation time in blood pump applications is limited by blood damage caused by mechanical stress within the pump. To overcome this limitation, a new pumping principle is introduced. It is based on wave propagation inside a flexible tube in combination with positive displacement. The tube stimulation is generated by an electromagnetic actuator. A shock head is used to couple the stimulation into the flexible tube. Due to that arrangement, there is no direct contact between the fluid an moving parts. This reduces the mechanical stress and the external surface coming in contact with blood. In contrast to common roller pumps higher frequencies and much smaller amplitudes of tube stimulation are used. In this way it is possible to reach a pumping operation without a complete tube occlusion. This ensures gentle pumping without damaging the blood cells. Our measurement of the pump curve demonstrates the capability of the pumping concept. The measured trajectory of the shock head confirms the pumping operation without complete tube occlusion.

2:50 – 3:10 p.m. Coffee break and Visits of Expositions	
3:10 p.m.	D. Dinulovic, M. Shousha, M. Brooks, M. Haug (D-Garching), T. Petrovic (SU-Nis)

Miniaturized Push-Button Rotational Energy Harvesting Generator

This work presents a development and miniaturization of a rotational electromagnetic energy harvesting (EH) generator. The energy harvesting generator is driven mechanically by pushing the button. The energy harvester system has an integrated mechanism for movement conversion. This mechanism converts the linear movement of the button into rotation with a rotational speed of 1000 rpm. An electromagnetically part of harvester consists of in FR-4 embedded multilayer planar coils and of multipole NdFeB hard magnets. The miniaturized energy harvester generates a maximum open circuit output voltage of about 500 mV with duration of about 2 s and a maximum short circuit output current higher than 40 mA.

3:30 p.m.	R. Lichtenheldt (D-Weßling), F. Becker, K. Zimmermann (D-Ilmenau)

Screw-driven Robot for Locomotion into Sand

The locomotion into sand is needed in various applications, but due to the complex mechanics of granular matter it causes special difficulties. High resistance forces on penetration systems and parameter dependent behavior, like stable or instable boreholes, complicate the design of mobile robots for the locomotion in sandy soil.

The most effective state of the art devices deploy hammering mechanisms. Screw-driven systems arise more and more in the literature, as they promise to be a simple, robust and low-cost solution.
In this paper, an autonomous drilling robot for the locomotion into sandy soils is presented. The design is based on theoretical modeling and experimental analyses of the screw drive aiming to minimize the needed torque and to maximize the locomotion speed. The presented prototype is able to reach a depth of 20 centimeters within a minute with a torque of 0.66 Nm.

3:50 p.m.	M. Franke, K. Röbenack, R. Weiß (D-Dresden), St. Palis (D-Magdeburg)

Control of a Tower Crane by Means of Algorithmic Differentiation

Deriving Euler-Lagrangian equations of motion for sophisticated mechanical systems symbolically often results in complex and large expressions. Based on algorithmic differentiation we present an alternative to the direct implementation of this equations. The Lagrangian provides the starting point for deriving the equations of motion and not necessarily has to be given explicitly. Algorithms containing loops or other control structures will work as well. We will demonstrate the usage of this alternative differentiation method on the system of a tower crane. Experimental results will complete this proposal.

4:10 p.m.	D. Kupriyanov, A. Lukin, N. Kopev, I. Ustiugov, R. Skripko, A. Meshkov (RUS-St.Petersburg)

Designing of software-hardware robotics educational complex

This work is devoted to the development of an educational robotics complex used for teaching the basics of programming to students of the department of Mechatronics. The main characteristics of the previous complex are given, the preconditions for its replacement are indicated, the basic requirements for the projected complex are determined. Also, various stages of the development of the complex are described, the advantages and disadvantages of the prototypes are analyzed, and tasks for further work are set.

End of Session

Poster Session 3.1 Mechatronics – Integrated Actuators

Time: Tuesday, 12.09.2017, 12:00 noon – 1:30 p.m.
Location: Foyer Humboldtbau

D. F. M. da Cruz, H. Lepikson (BR-Bahia), W. L. Weingaertner (BR-Santa Catarina)

A Parallel Robot With Three Translational Degrees Of Freedom For Machining Operations

This paper proposes a new machine tool structure design for machining based on a Delta Robot architecture as object of study, known as Tsai's Manipulator, patented by Tsai in 1997. The new architecture employs only rotary joints instead of spherical ones as it is usual for Delta Robots. The rotary joints allow its mount under pretension to eliminate clearances or backlash, avoiding the use of expensive spherical joints. All the other mechanical parts are standard components, which makes the solution attractive in terms of cost. A simplified inverse kinematic solution over the one proposed by Tsai is presented, based on a practical approach. The simplified solution reduces the number of steps to solve the inverse kinematics without any loss of performance. In addition, a solution to deal with the coupled axis without parasitic motion is presented. To increase the accuracy and the stiffness of the robot, a special attention was given to the rotary joints using preload rotational ball bearing joints. The structure parts were manufactured mostly by laser cutting with almost no complementary machining processes. In order to evaluate the proposed solutions, a prototype was built and a dedicated control software was developed for this particular robot. Workpieces were milled with the robot to demonstrate its capability and the advantages regarding the proposed machine architecture.

J.-Y. Chen, Y.-L. Lin, Ch.-Ch. Lin, B.-Y. Lee, (TW-Huwei Town)

Development of Inspection System for Tool Presetter

In order to conform to the concept of smart factory for industry 4.0, this paper developed a low-cost tool measuring machine included the structure design, hardware planning of the server, electromechanical control, drive system, human machine interface, communication between hardware and software, software development, and so on. The proposed measuring system provided more flexibility and integration with peripheral equipment for the requirements of industry 4.0. Compared with a Germanic measuring machine, experimental results showed that the percentage of errors of the designed inspection instrument were 0.004 % and 0.003 % for the tool length and diameter measurements of a square end mill, respectively.

J. Tafur, B. Barriga (PER-San Miguel)

Optimal control for a prototype of an active magnetic bearing system

Session 3.2 Biomechatronics

Time: Wednesday, 13.09.2017
Location: Humboldtbau | Lecture Room 211/212
General Chair: H. Witte (D-Ilmenau)

Chair: N. Kizilova (UA-Kharkov)

9:00 a.m.	Invited Lecture E. Andrada (D-Jena und D-Ilmenau)

New aspects of bipedal locomotion in birds

9:40 a.m.	K. Söhnel, E. Andrada (D-Jena), M. H. E. de Lussanet, H. Wagner (D-Münster), M. S. Fischer (D-Jena)

Kinetics of jumping regarding agility dogs

Dog agility is a popular sport discipline, characterized by jumping at high speed and with fast directional changes. Systematic scientific research regarding kinetics in jumping agility dogs is scarce. For the first time, we examined kinetic parameters for single legs in take-off and landing a hurdle jump. Further, we compared straight jumps and wrap jumps.
Simultaneous kinetic and kinematic data were recorded from 10 advanced agility Border collies jumping over two consecutive hurdles. Ground reaction forces (GRF) were recorded for hindlimbs (HL) during take-off and forelimbs (FL) during landing.
For straight jumps, we found synchronous HL touchdown at take-off phase. GRF shows similar progression in both HL. During the landing of a straight jump, the FL show skipping gait pattern, with first touchdown of the trailing limb (TrF), followed by touchdown of the leading limb (LdF). We found shallower angle of attack and a higher decelerative impulse for the LdF than theTrF. For wrap jumps, HL touchdown was synchronous during the take-off phase, but the GRF pattern differed. The GRF progression indicated that the take-off pattern of the HL acts like a differential gear. The touchdown of FL was synchronous during landing, but like the HL they showed a different GRF progression. Peak vertical and mediolateral forces seem to be higher for the right forelimb than the left forelimb, to resist inertia effects and to continue turning.

10:00 a.m.	V. Pushenko, N. Kizilova, E. Ustimenko (UA-Kharkov)

Kinematics of catching arms in insects: towards optimal design of robotic manipulators

Construction of the running, jumping, swimming and burrowing legs in insects has been studied, while the catching hands in the predatory insects remain unstudied. Anatomy and dynamics of the jumping and swimming legs have been used for biomimetic design of the corresponding robotic legs. One of the known predatory insects is preying mantis (Mantidae family, order Mantodea) catching its prey by the 4-link forelegs. In this paper the morphology of the first pair of the legs of mantis fulfilling the function of catching prey arms has been studied for the biorobotic aims.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions

Chair: E. Andrada (D-Jena)

10:40 a.m.	K. Siedler, C. Behn (D-Ilmenau)

Control of Compliant Robotic Systems with muscle-like Actuators and Saturated Feedback

This paper is devoted to the problem in controlling a compliant robotic system by means of actuators with muscle-like properties, which underlie prescribed bounds due to the natural muscle behavior. A typical example to demonstrate the effectiveness of developed control schemes is the choice of a (inverted) pendulum with higher degree of freedom. Due to the force restriction of the driving muscle forces, we have to sought (saturated) feedback strategies to control the system behavior (e.g. tracking of paths) which have to be limited a-priori. A suitable control variable can be generated by adaptive controllers, e.g., a PID-λ-stabilization. But, the classical torque control variable has to be converted to the muscle force at the joints, and the joint angle velocity has to be converted to the contraction velocity. The effective force at every joint is the difference of the antagonistic muscles pairs with the muscle characteristic curve of HILL (force-velocity-relation). The aim is now, to hold the control variable inside the area restricted by the muscle pairs. Several simulations show the effectiveness of the designed controllers.

11:00 a.m.	J. Kräml, C. Behn (D-Ilmenau)

Multi-segmented Artificial Locomotion Systems with Adaptively Controlled Gait Transitions

This paper is devoted to the analysis and simulation of multi-segmented artificial locomotion systems. We restrict our investigation to a crawling system which is moving along a straight line. Recent results from the examined literature present investigations of short worms ($n<4$). In contrast to this, the developed mechanical model in this paper consists of a chain of 10 discrete mass points. Let us point out, that the presented investigations are not restricted to a fixed number of mass points. To achieve a movement of the system, the distances between neighboring mass points are controlled by viscoelastic force actuators. Due to a prescribed reference gait, an adaptive controller determines the necessary forces to adjust the prescribed values. Then, due shortening and lengthening of these distances together with a spiky ground contact at the mass point surface, we achieve a global movement of the whole system – called undulatory locomotion. Specific prescribed gaits are required to guarantee a controlled movement that differ especially in the number of resting mass points and the load of actuators and spikes. To determine the most advantageous gaits, numerical investigations are performed and a weighting function offers a decision of best possible gaits. A gait transition algorithm for an autonomously change of the locomotion velocity and number of resting mass points in dependence on the spike and actuator force load is presented and tested in numerical simulations.

11:20 a.m.	V. Musalimov (RUS-St.Petersburg), G. Aryassov, I. Penkov, S. Zhigailov (EST-Tallinn)

Imitation of the human hip joint motion

The article describes the experimental and analytical approach for obtaining a mathematical model of the mechanical pelvis system in the frontal plane, based on input and output signals captured from twenty-seven different experiments simulating human pelvic motion, with corrections for possible subsequent usage of scientific results in mechanotherapy. By help of proposed model and using the SimMechanics graphical applications is possible to calculate the masses, properties and dimensions of the elements of imitator`s mechanical construction, by the way determining the kinematic and dynamic parameters of it and to apply a new research methodology for similar type of imitators in comparison with the methodology presented before. Finally, the kinematic scheme of pelvic motion model was created and a test prototype was made. By help of designed prototype laboratory tests with twenty-seven combinations of pelvic rotation angles, loads and duration time were made. Results were compared to the results obtained by visual capture system. On base of obtained results functions of pelvic motion were derived and plane trajectories were proposed.

11:40 a.m.	O. Kröning, H. Rothe (D-Hamburg)

Requirements and Potentials of Human Kinetic Energy Harvesting Technologies with Focus on Electromagnetic Conversion Methods

In the recent years, energy harvesting has become increasingly popular for powering low-energy devices. Therefore, human power has become a promising energy source in providing electrical energy. Thus, the general principles, structures, requirements and potentials of human kinetic energy harvesting technologies are presented.

Commonly, human kinetic energy harvesting systems have to be adjusted to the human locomotion. For the purpose of maximizing the power output, results of biomechanical analyzing methods are presented to identify resonant frequencies and bandwidths. With focus on inertial electromagnetic generators, further challenges and potentials are discussed to optimize the power conversion. In doing so, mechanical and electrical characteristics of the generator structure are examined and optimization problems are derived. One major issue within power maximizing is to match the resonant frequency and achieve a suitable electromechanical coupling. Parameter dependencies are identified by using analytic and numerical representations of generic electromagnetic generators.

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions

1:30 p.m. – 4:30 p.m. Ehrenkolloquium in memoriam an Prof. E. Kallenbach

Chair: C. Behn (D-Ilmenau)

1:30 p.m.	Th. Helbig, A. Schmidt, S. Roland, A. Giese, T. T. Finke (D-Ilmenau), T. Schmidt (D-Jena), H. Witte (D-Ilmenau)

Characterizing the outer ear transfer function in dependence of interindividual differences of outer ear geometry

The outer ear transfer function can be used to describe the influence of the outer ear canal and its geometric variance in cross-section as well as its path on the sound field in the ear canal and the sound pressure level resulting at the ear drum. The variance of outer ear geometry is described by analysis of polysiloxane castings of the outer ear. Algorithms are developed to determine various parameters of the outer ear geometry and to gain access on a huge amount of data (over 100.000 data sets). Sound transmission in form of the outer ear transfer function is analyzed for various outer ear geometries using a finite element model as well as an experimental setup. In both cases sound (frequency band: 20 Hz to 20 kHz) is send to a model of the outer ear as a plane wave parallel to the plane of the Pinna.

1:50 p.m.	L. Merker, Ch. Will, J. Steigenberger, C. Behn (D-Ilmenau)

Object Contour Sensing using Artificial Rotatable Vibrissae

Recent research topics in bionics focus on the analysis and synthesis of mammal's perception of their environment by means of their vibrissae. Using these complex tactile sense organs, rats and mice, for example, are capable of detecting the distance to an object, its contour and its surface texture. In this paper, we focus on developing and investigating a biologically inspired mechanical model for object scanning and contour reconstruction. A vibrissa - used for the transmission of a stimulus - is frequently modeled as a cylindrically shaped Euler-Bernoulli-bending rod, which is one-sided clamped and swept along an object translationally. Due to the biological paradigm, the scanning process within the present paper is adapted for a rotational movement of the vibrissa. Firstly, we consider a single quasi-static sweep of the vibrissa along a strictly convex profile using nonlinear Euler-Bernoulli theory. The investigation leads to a general boundary-value problem with some unknown parameters, which have to be determined in using shooting methods. Then, it is possible to calculate the support reactions of the system. These support reactions together with the boundary conditions to the support, which all form quantities an animal solely relies on in nature, are used for the reconstruction of the object contour. Afterwards, the scanning process is extended by rotating the vibrissa in opposite direction in order to enlarge the reconstructable area of the profile.

2:10 p.m.	R. Fischer, M. Stubenrauch, A. Straube, K. Wedrich, B. Goj, H. Bartsch, M. Bichra (D-Ilmenau), H. Rothe (D-Heiligenstadt), H. Witte (D-Ilmenau)

System for Automated Cell Cultivation and Analysis

Contrary to highly automated industrial processes, cell cultivation is still based on manual labour. Especially for mechano-sensitive cells this is disadvantageous, since handling processes provoke inertial forces which cannot be reproduced. To challenge this problem, we developed an automated, modular cell cultivation system based on a rapid prototyping approach and open source electronics. Cells are cultured in mechanically fixed fluidic modules featuring micro cultivation chambers. These are positioned in an open framework which houses fluidic supply systems and a three-axis drive for positioning of analytical instrumentation. The system is controlled via a touchscreen interface and distributed microcontrollers inside the modules and components.
The supply infrastructure provides proper physical, chemical and biological environmental parameters. These parameters act as a stimulus for cell reactions like differentiation or synthesis of specific metabolites and thus enable the investigation of cellular stimulus-response-mechanisms.

2:30 p.m.	T. Nowack, C. Dutschmann (D-Ilmenau)

Identify pointing and waving in gesture based Human-Machine-Interaction

The gestures "pointing" and "waving" are investigated with regard to their characteristic properties and their suitability for using in gesture based Human-Machine-Interaction (HMI). The MS Kinect 2® as usable motion capturing device is proofed. A description of different basic types of gestures in human-to-human interaction is given and the requirements for the HMI are discussed. A general phase model in combination with the movements of a gesture execution is explained. For the technical recognition of these movement sequences, parameters are defined which are based on the joint data of the Kinect. Detecting the pointing gesture an angle, its angular velocity and optional a holding time are used. The waving gesture is also detected with the help of an angle and its periodicy. To evaluate these angles and the necessary threshold values, several experiments had been done.

2:50 – 3:10 p.m. Coffee break and Visits of Expositions

Chair: Th. Helbig (D-Ilmenau)

3:10 p.m.	E. Bances, D. Bahena, H. Witte (D-Ilmenau)

Wireless System for Breathing Analysis During Free-Running Locomotion in Mammals

For many years, researchers have studied the interaction between breathing and locomotion. It is evident that a respiratory flow occurs with stride during locomotion in any vertebrate. Besides, the discussion was focused on the amount of air volume displaced in the lungs due to this interaction.

This paper describes a wireless system to measure the air flow and to calculate the ventilation volume during free-running mode. This is due to the fact that previous studies have been implemented on treadmill and conditioned laboratories, exerting a high stress in the animals. The functional test of air flow system was performed in a closed sports center (50x30m ^ 2). The experiment characteristics were temperature around 20°C, without wind resistance and a stable wireless local network (WLAN). As a results, the wireless communication reaches a range over 60m with continuous transfer of data packets and high transmission rate.

3:30 p.m.	C. Schilling, M. Stubenrauch, S. Köhring, D. Voges, H. Witte (D-Ilmenau)

Aspects of functional electro-chemical biocompatibility in Microsystems

Signal transport as well as signal processing in biosystems are based on ion fluxes.
A general understanding of functional electro-chemical biocompatibility aspects in the area of microsystems are introduced, derived from experiences in several research projects. Our research approaches are focused on hybrid microsystems, to cultivate and/or accommodate biologic specimen inside technical structures even for long-term experiments. Ion flux based microsystems have to provide the capability to handle extremely small amounts of signal carrying substances. This makes the substance and energy transfer on interfaces to be a crucial and dynamic part of all structures and functions. We tested this approach in several experiments. One setup is a planar flow-through chamber with two electrodes of the second kind in which the galvano-tactic behaviour of protozoa could be observed. A double-chamber setup utilizes a cation-permeable membrane to separate two fluidic compartments. This gradient generates a reproducible potential on a physiologically relevant level. To avoid disturbance of side effects like polarization and transition impedance, non-electric control of ion flux can be implemented using UV-light instead of metallic electrodes. Beside the low feedback of the signal derivation of cell membrane potentials, also a new impulse can be set for the elucidation of control mechanisms for cell motility, cell differentiation, and morphogenetic regulation.

4:10 p.m.	H. Witte (D-Ilmenau)

Outlook on biomechatronics

End of Session

Poster Session 3.2 Biomechatronics
Time: Thursday, 14.09.2017, 12:00 noon – 1:30 p.m.
Location: Foyer Humboldtbau

C. Behn, L. Ackermann, C. Will, T. Helbig, J. Steigenberger (D-Ilmenau)

Vibrissa-based Design of Tapered Tactile Sensors for Object Sensing

Numerous mammals possess whiskers (tactile hairs, also known as vibrissae) to explore their environment. These complex mechano-sensitive vibrissae are located, e.g., in the snout region (mystacial vibrissae). Because of the deformation of the vibrissa by contact with objects and obstacles, the animal gets additional information about the environment. Despite different morphology of animal vibrissae (e.g., cylindrically or conically shaped, precurved, multi-layer structure), these biological tactile hairs are modeled in a mechanical way to develop and analyze models concerning their bending behavior with a glance to get hints for a technical implementation as a technical sensor. At first, we investigate the bending behavior of cylindrically shaped and tapered beams which are one-sided clamped and are under the load of an external force, using the Euler-Bernoulli non-linear bending theory. Then, a quasi-static sweep of these beams along various obstacle profiles is used for an obstacle profile reconstruction procedure. While scanning the object, the clamping reactions are determined, which are the only observables an animal relies on in biology. In plotting these observables and using them in a reconstruction algorithm to determine the scanned contour, we try to identify special features in dependence on the different geometries of the beams. The clamping reactions tremendously depend on the form and position of the profile which is shown in several numerical simulations.

S. Wenzel, R. Fischer, T. Nowak, M. Stubenrauch, H. Witte (D-Ilmenau)

Automated cell cultivation and analysis: an approach for a user interface design

While automation is standard in most industrial and research fields, cell cultivation is still dominated "handling", manual processes. To improve the situation, our group focusses on the development of a bio-centred, automated cell cultivation tool. Modular design may help to realize a variety of experiments. Cultivation processes are observed and controlled via a graphical user interface. This article describes the systematic approach, the overall specification (with process analyses) and the preliminary results for the prototype of a graphical user interface.

M. Scharff (D-Ilmenau), J.H. Alencastre (PE-Lima), H. Witte, K. Zimmermann, J. Steigenberger, C. Behn (D-Ilmenau)

Investigations on the Mechanical Relevance of Prominent Vibrissa Features for Surface Texture Detection

The tactile hairs of animals are used as paradigm for artificial tactile sensors. In the case of mystacial vibrissae, the animals can determine the distance to an object, recognize the shape of the object and detect the surface texture of the object.

The goal is to design an artificial tactile sensor inspired by the natural paradigm. In the present work, the vibrissa and the follicle-sinus-complex are modeled as a one-sided clamped beam within the limits of the non-linear Euler-Bernoulli beam theory. The theoretical background of the function principle and the effects of typical properties of the natural vibrissa, e.g., a tapered shape and a pre-curvature while operating in surface texture detection are analyzed. The beam-surface contact is described by Coulomb's law of friction. When the beam is in touch with the surface, a quasi-static displacement of the support takes place. As a consequence of the displacement the support reactions are changing. The resulting support reactions are analyzed in parameter studies and beneficial levels of tapering and pre-curvature are identified.

J. L. Zárate Moya (D-Ilmenau), A. Meshkov, A. Lukin (RU-St. Petersburg)

Design and Control of a Flapping Wing System Test Bench

The design of an adaptable system to analyze the properties of flight dynamics in flapping wings systems helps to study their characteristics and allow the use of different control techniques to improve their performance. This work presents the design of a prototype test bench based on a mathematical modeling of a balancing beam with a flapping mechanism with wings. This mechanism consists of a bar that has as a rotational degree of freedom contained in the vertical plane where in one end the flapping mechanism is located. This movement is produced by the thrust force due to wings flapping coupled to a gear set and a motor. The tunable speed of rotation in the direct current motor allows controlling the force of thrust managing the movement of the bar towards a determined angular position measuring by an Inertial Measurement Unit (IMU). The data obtained and the control system application is performed using the MATLAB SIMULINK toolbox and Arduino device as interface between system and computer. The model was obtained experimentally, the control was implemented in real time and compared with the mathematical model of the system.

T. Kneip, J. Heubach, S. Seitelmann, P. Wagner, H. Witte, T. Helbig, D. Voges (D-Ilmenau)

Construction of a cilia inspired carriage system

Hair-like appendices, so called cilia, occur on the surface of cells of prokaryotes as well as eukaryotes. In coordination with each other, these eukaryote cilia perform coordinated movements, which allow them either to locomote themselves or to move objects along their surface. Even multi-directional transport could be observed.
For industrial issues, this phenomenon could be used as a paragon to design mechanisms on microscopic and macroscopic level to sort and redistribute sensitive components, which cannot be handled by conventional grippers.
This article describes the design process and realization of a macroscopic demonstrator for this principle. It can be shown, that the bio-inspired idea of a mechanical implementation of cilia-like object-transportation in air may be successfully embodied on macroscopic scale.

Session 3.3 Mechanism Technology

Time: Tuesday, 12.09.2017
Location: Humboldtbau | Lecture Room 210
Chair: L. Zentner (Ilmenau)

9:00 a.m.	Th. Speicher, M. Berger (D-Chemnitz), K. Hauschild, A. Fricke (D-Saarbrücken), Th. Heske (D-Türkenfeld)

Optimizing a biopsy needle using a simulation model

The method of biopsying biological tissue is an established procedure of minimally invasive medicine to extract samples for the determination of the presence or extent of a disease. Therefore punch biopsy is the most frequently applied method in case of prostate or breast cancer. The biopsy system is monitored during the penetration process into tissue via sonography. These observations of the procedure showed a considerable deflection of the needle tip. It is caused by unbalanced forces acting on the tip and by the low bending stiffness of the system itself.
Government financed experimental studies using realistic phantom tissue have been conducted to quantify the needle deflection and to develop a mathematical approach to simulate this effect. This simulation has used a combination of a deformable model of the biopsy system in combination with a parameterized tissue model in multibody simulation software Recurdyn. It is now possible to anticipate the needle deflection, to get to know about the acting forces and to optimize the geometry of the needle tip.

9:20 a.m.	A. Milojević, N. T. Pavlović, N. D. Pavolović (SRB-Nis), S. Linß, L. Zentner (D-Ilmenau)

A new multi-notched flexure hinge based on topology optimization with discrete beam elements

9:40 a.m.	S. Hügl, L. Zentner, St. Griebel (D-Ilmenau), O. Majdani, Th. S. Rau (D-Hannover)

Analysis of the customized implantation process of a compliant mechanism with fluidic actuation used for cochlear implant electrode carriers

Patients suffering from severe to profound hearing loss, can be treated with a cochlea implant to restore hearing due to direct electrical stimulation of neurons. Hence, a silicone electrode carrier has to be implanted into the spiral-shaped organ of the cochlea (inner ear). The here presented fluid actuation by use of a compliant mechanism within the electrode carrier is designed to enable an active steering of the implant and its bending in order to achieve contactless insertion into the cochlea and a preset final position under a certain pressurization. An averaged small, middle and large spiral cochlea path has been defined based on the segmentation of 23 3D-datasets of human cochleae in order to enable the synthesis of individual implants. The fit of these implants within all three sizes of cochleae was adapted by variation of the pressure load which induces the bending of the implant.

10:00 a.m.	R. Voßwinkel (D-Dresden), J. Tong (D-Kaiserslautern), K. Röbenack (D-Dresden), N. Bajcinca (D-Kaiserslautern)

Stability bounds for systems and mechanisms in linear descriptor form

Mathematical models for simulation and control of systems and mechanisms naturally arise in a descriptor form. The stability analysis of descriptor systems, involving free parameters as uncertainties or design qualifiers is subject of this paper. Two approaches for the calculation of the stability boundaries in the underlying parameter space are discussed. The first one uses a quantifier elimination method, while the second one is based on the direct solution of the Lyapunov equation. The computational methods are exemplary demonstrated on Chua's circuit.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions

10:40 a.m.	M. Tomić, A. Milojević, M. Milošević, N. T. Pavlović, N. D. Pavolović (SRB-Nis), H. Handroos (FIN), S. Linß (D-Ilmenau)

Analytical model of conductive graphite foam based sensors characteristics

Modern and emerging technologies enabled us more comfortable and pleasant everyday life. Sensors are elements that have the function to collect these information from the environment and to forward them to the processor for further processing. There are some examples of the low-cost sensor for measuring the force (pressure) or the displacement realized by utilizing conductive elastomer. These elastomers exhibits property of changing the electrical resistance when the elastomer is deformed. This paper introduced a novel conductive graphite foam based sensors. Price for producing this kind of sensors is very low, but the problem is their accuracy.

The main aim of this paper is to develop the analytical model of the conductive graphite foam sensors for measurement of the displacement. By measuring the changes in the electric resistance between two points of the foam and using the developed analytical model it should be possible to accurately estimate the displacement when the conductive foam is deformed. The method of least squares will be used to approximate the measured voltage changes for the applied displacement of the graphite conductive foam. The data for pressing the foam, and for release the foam will be observed separately. Polynomial third-order approximation will be used as an approximation function.

11:00 a.m.	A. Czmerk, A. Bojtos (H-Budapest)

Stiffness investigation of pneumatic cylinders

Pneumatic cylinders are widespread used in industrial machines these days. They are invented in various mechanisms like manipulators, and in tasks with higher force effort because of their reliability and robust design. The low level of stiffness is a significant disadvantage of pneumatic cylinders which arises from the compressibility of the air in the chambers. This property is typical for all pneumatic equipment, but using a servopneumatic system this is a significant disadvantage. Servo-pneumatic systems are unique in that they can position the

piston at any point in the stroke length. With a sufficiently large disturbance, the piston does not remain in the desired position, but will displace, and returns to the starting point after the end of the disturbance. Of course the displacement can be controlled by the controller of servopneumatic systems, but the phenomenon of recovering from air compressibility remains characteristic. The displacement itself, compared with mechanical constructions, can be interpreted as a kind of flexible deformation, and the flexibility is caused by compressed air in the cylinder chambers.
The main contribution of the paper is to determine the resulting stiffness, and the restoring force of the air in the pneumatic cylinder chambers using laws of mechanical engineering.

11:20 a.m.	L. Stubbig (D-Ilmenau), R. Lichtenheldt (D-Köln), F. Becker, K. Zimmermann (D-Ilmenau)

Model-based development of a compliant locomotion system for a small scout rover

All currently active planetary exploration robots employ wheels for locomotion. In this work an alternative robotic locomotion concept is examined: the rimless wheel, also known as whegs. It has been proven to be successful in traversing rough terrain on earth and inhibits an appealing simplicity in its mechanics and controls. These aspects along with its inherent redundancy make the rimless wheel particularly suited for planetary exploration. The rimless wheel's kinematics and compliant spokes are analytically examined using mechanical models. The dynamics of these models are explored in a computational multi-body simulation which confirms the conclusions drawn from the analytical models about running, climbing and movement on rough terrain. A parameter variation then yields a set of suitable parameters for a future scout rover. The application in sand is considered separately both analytically and computationally. Based on these results a single wheel is build and tested on the conclusions drawn from modelling and simulation. These experiments provide strong support that the two-sided goal of efficient movement on hard and flat surfaces as well as reliable negotiation of rough terrain can be achieved with the developed locomotion system.

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions
12:00 noon – 1:30 p.m. Poster Session | Foyer Humboldbau

S. Linß, Ph. Schorr, St. Henning, L. Zentner (D-Ilmenau)

Contour-independent design equations for the calculation of the rotational properties of commonly used and polynomial flexure hinges

Flexure hinges are often used as revolute joints in high-precision compliant mechanism, but without simulations the accurate prediction of their contour-dependent deformation and especially planar motion behavior is a challenging task. This paper presents contour-independent general design equations for the explicit calculation of the rotational stiffness, maximum angular deflection and rotational precision of various notch hinges in dependence of the geometric parameters. The non-linear analytical model describes a clamped beam with included flexure hinge which is loaded with a moment or a transverse force at its free end. In addition to the common semi-circular, corner-filleted, and elliptical flexure hinge, the high-performance polynomial hinge with five different orders is investigated. The deviation of the calculated results compared with the analytical solution depends on the contour and it is mostly relative low for the suggested parameter range. Furthermore, finite elements method (FEM) results correlate well with the predictions based on the analytical solution as well as the solution with the simple, concise and uniform design equations.

Topic 4

Systems Engineering

Session 4.1 | Components and Systems
Session 4.2 | Processes and Methods

Session 4.1 Components and Systems

Time: Tuesday, 12.09.2017
Location: Humboldtbau | Lecture Room 202
Chairman: U. Kletzin (D-Ilmenau)

9:00 a.m.	R. Lima Stoeterau, S. Y. Araki, E. G. P. Bock, J. Rocha (BR-Sao Paulo)

Micro Bearing Analysis for Implantable Ventricular Assist Devices

9:20 a.m.	M. Petrich, B. Schrodin, U. Kletzin (D-Ilmenau)

Material selection method for composite springs

In this work, extensive information about various fiber and matrix materials was compiled. This applies in particular to the mechanical properties, the impact of environmental influences as well as the technological and the economic aspects. These data have been implemented into a calculation table in Microsoft Excel. This system offers the user the possibility to weigh all material properties to different degrees. In order to determine these, the resulting material properties are initially calculated for all combinable fiber-matrix pairings. These standardized material properties are used to evaluate each material combination.
Furthermore, a top-down-ranking is generated and presented with detailed information about the composites. Three examples of composite springs have shown the validation of the method. On the basis of the knowledge from this research, general rules could be concluded and formatted as graphical workflows for fiber and matrix selection, which are valid beyond composite spring applications. An outlook on further research could be the implementation of more materials, e.g. organic fibers, to enlarge the database. Other enhancements could be steps for geometry and manufacturing details. This would lead to more optimized recommendations. In addition, for special components, a whole design feature could be created, that combines the spring layout with the material selection process.

9:40 a.m.	J. Schleichert, U. Kletzin (D-Ilmenau)

Creep and relaxation behavior of spring steel wires

This paper deals with creep and relaxation behavior of spring steel wires and helical compression springs. The mathematical description of this behavior over time regarding torsional stress is regarded closely. The derived equations based on the NORTON-BAILEY creep law are used for the evaluation of experimental data examining the relaxation as well as the creep behavior of different types of spring steel wire under torsional stress. As a part of the experimental approach, the heat treatment, which the wires were exposed to, as well as the level of relaxation stress and the surrounding temperature are varied. In this context the main influencing factors regarding creep deformations are discussed and creep specific characteristics are determined. Finally, the effect of different material, heat treatment, surrounding temperatur and level of stress on the creep behaviour are discussed and material constants identified.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions
12:00 noon – 1:30 p.m. Lunch and Visits of Expositions **12:00 noon – 1:30 p.m. Poster Session | Foyer Humboldtbau**

Session 4.2 Processes and Methods

Time: Wednesday, 13.09.2017
Location: Humboldtbau | Lecture Room 204
Chairman: C. Weber (D-Ilmenau)

9:00 a.m.	K. Pfeffer (D-Ilmenau), W. Eißler (D-Wiesbaden)

Experimental Investigation of an Efficient Method for Measuring Turbocharger Maps

The purpose of hot gas test benches is the survey of operating maps for compressors and turbines of exhaust gas turbochargers. The recording of turbocharger maps is usually ensured through measuring points on constant speed lines at a quasi-stationary operating point of the turbocharger. At hot gas benches, the operating points can be controlled by the parameters hot gas mass flow and gas temperature on the turbine side of the turbocharger as well as the output air flow resistance at the compressor side. Because of the simultaneous usage of the controls, long settling times are required to reach a turbocharger operating point that can be assumed to be stationary.
The present paper takes up by implication that even transient measured characteristic operation points are comparable to stationary measured ones. Using the example of an exhaust gas turbocharger with fixed geometry, the experimental investigation of influences from a transient operation mode on characteristic diagrams for compressor and turbine are investigated experimentally. It is shown how far these unsteady and quasi-steady measured maps are comparable. Furthermore, the applicability of the different control variables for the test bench control is exposed and the negligible influence of the rotor inertia torque is revealed. By transient operation for measurement of characteristic diagram, the possibility of a significant time saving is expected compared to that of quasi-steady operating points.

9:20 a.m.	H. Weiß, T. Bauer, M. Eichhorn (D-Ilmenau)

Automatic Optimization of Load Angles for a Linear Hybrid Stepper Motor

The objective of this contribution is a linear direct drive based on the working principle of hybrid stepper technology. Commonly, the phases of the linear hybrid stepper motor (LHSM) are commutated sinusoidal with a constant load angle of 90 degrees. Due to delay times of sensors, actuators and hardware, the phases' coils are not energized optimally in terms of maximum force application. Thus, variable load angles subject to velocity are introduced. This contribution comprises the optimization of the load angles. To solve this one-dimensional optimization task, bracketing methods can be used. These algorithms work without derivatives and find the minimum through iterative decreasing of the interval until a desired tolerance is achieved. Regarding the implementation, signal processing has to be done beside the optimization algorithm to ensure feasible solutions. The entire optimization process can be carried out automatically on the test rig. As a result, a characteristic curve is obtained describing the optimal load angle to velocity relation. Including the directionality, the characteristic curves are distinguished between forward and backward drive. Further properties of the optimization algorithm such as convergence and reproducibility are examined and discussed. The curves are implemented on a real-time system facilitating a comparison with constant load angle commutation. Velocity control measurements exhibit an improved performance, especially at high motion dynamics.

9:40 a.m.	B. Leistritz, W. Kattanek (D-Ilmenau)

Design methodology for application-specific electromagnetic Energy Harvesters

Energy-efficient and high-performance sensor and actuator systems are required for a wide range of industrial 4.0 applications. In order to increase the intelligence of such systems, an increase of the provided energy, a reduction of the energy consumption per service, and the development of adapted energy management components are necessary. The energy required can be provided in various ways. The aim of the current paper is the conversion of kinetic energy from the application environment into electrical energy with the help of electromagnetic energy harvesters.

Electromagnetic energy harvesters are characterized by at least one magnet and one coil. A time-varying magnetic field in the coil is caused by a relative movement of the two parts. Due to the freedom in the number and arrangement of the elements, different basic topologies are possible. This allows optimally adapted designs, but also makes a fast design difficult. For this purpose, a systematization and design methodology is developed for a cost-effective design of adapted energy harvesters for application-specific boundary conditions. It is implemented as a design tool in MATLAB®, which performs an automated comparison between different basic structures. Prior to presenting first results of these structural comparisons, the general structure of the design process is explained. It is shown that the application-specific requirements are most important for the evaluation of the basic structures.

10:20 – 10:40 a.m. Coffee break and Visits of Expositions

10:40 a.m.	R. Knoblauch, J. V. M. R. Costa, W. L. Weingaertner, F. A. Xavier (BR-Florianópolis), K. Wegener (CH-Zürich)

Endless Diamond Wire Saw for Monocrystalline Silicon Cutting

The multi-wire sawing of silicon using diamond coated wire is an important process in the semiconductor and photovoltaic industry. The process is performed by pushing the silicon ingot against a wire web that moves forwards and backwards. As the feed direction of the wire reverses several times and the cutting speed is not constant, a proper investigation of the cutting process is very difficult to be performed. Aiming to experimentally investigate the multi-wire sawing of monocrystalline silicon, this work proposes a new test rig. For that, the requirements list is defined, and based on that, several conceptual solutions are proposed. The final solution is an endless wire saw that uses aerostatic bearing technology on its slides and rotatory bearings. The cut is performed by a looped diamond coated wire that spins around two Teflon discs. The silicon workpiece is mounted on a vertical aerostatic slide and pushed against the wire with constant force controlled by a counterweight system. Results of experiments on process characterization and tracking the same diamond grains for wear analysis are presented. The objective of tracking the same diamond grains for wear analysis is accomplished with the experimental setup.

10:50 a.m.	W. Scheidel, I. Mozgova, R. Lachmayer (D-Hannover)

Product Data Management in the Context of Industry 4.0

Industry 4.0, known as the fourth industrial revolution, generates great potential for self-organized, networked products. Industry 4.0 products have the ability to detect the environmental conditions and are enabled to communicate with each other. They collect lifecycle data, verify information and transfer them back to the product development. The information are used to create a new product generation. Product Data Management Systems (PDM) are used conventionally during the product development phase. In this paper the requirements of Industry 4.0 products are analyzed for PDM Systems. An analysis of six PDM Systems with the greatest market share are provided. At the example of a torch it is demonstrated how a PDM Systems is used to develop and manage the data of an Industry 4.0 product.

End of Session

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions

1:30 – 4:30 p.m. Ehrenkolloquium in memoriam an Prof. E. Kallenbach

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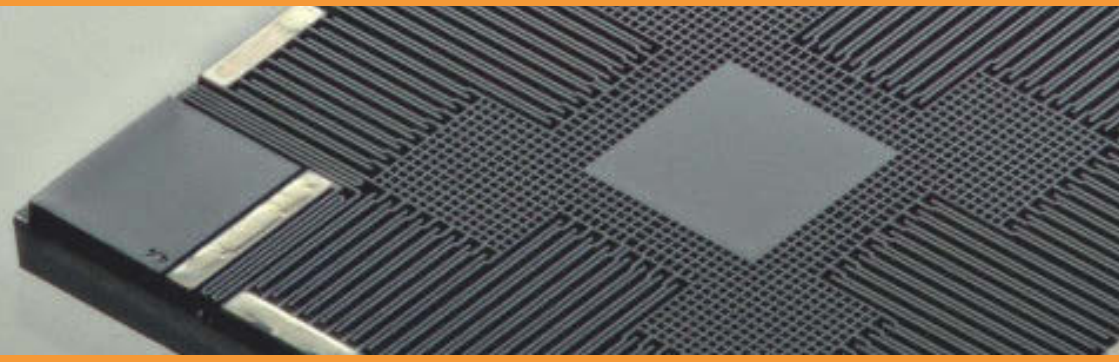

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Topic 5

Innovative Metallic Materials

Session 5 Metallic and Hybrid Materials and Simulation

Time: Thursday, 14.09.2017
Location: Humboldtbau | Lecture Room 012
Chairman: G. Lange (D-Ilmenau)

9:00 a.m.	G. Gevorgyan, R. Paukner, J. Erichsen, M. Weisse, P. Dawah (D-Roding)

HFRR Test Method with Stainless Steel Specimens for Gasoline Fuels

Reducing CO2 emission is a major challenge for the automotive industry. The different fuels (E10, E100, M15 etc.) that are used for gasoline systems not only influence the CO2 emission but also significantly influence the friction and wear behavior and subsequently the lifetime of powertrain components. The effect is much higher when biofuels are used. The characterization of tribological properties of gasoline fuels is necessary for a robust design which allows for permanent control of performance. The High Frequency Reciprocating Rig (HFRR) test concept according to ISO 12156 is the standard test method for evaluating the lubricity of diesel fuels. Up to now, no standard for gasoline fuels is known. The standardized HFRR test method uses 100Cr6 test specimens which are stable in contact with diesel fuel, but, unlike the stainless steel components used in gasoline fuel injection systems, is prone to corrosion in a gasoline environment typically containing a certain amount of water. This paper aims to develop a lubricity test method with stainless steel for gasoline fuels and reports first results for various fuel compositions.

9:20 a.m.	T. Brockmöller , P. C. Gembarski, I. Mozgova, R. Lachmayer (D-Hannover)

Design Catalog in a CAE Environment for the Illustration of Tailored Forming

Tailored Forming, which is explored in the Collaborative Research Centre 1153 at the Leibniz University Hannover, is a highly sophisticated set of manufacturing technologies that allow producing hybrid forming parts consisting of two different materials. In this paper, two elements of a computer-aided engineering environment are characterized that aims at assisting a designer in synthesis of such components. In order to determine the application potential of Tailored Forming, TRIZ-Reverse and its application is introduced. The resulting Tailored Forming Contradiction Matrix documents the Knowledge of Applicability for this manufacturing technology. Afterwards, design catalogues are discussed as repositories for detailed Tailored Forming Design Knowledge, exemplarily shown for drive components. Both then are integrated to a knowledge-based system that allows reasoning about the design of Tailored Forming components. The resulting concept then may be processed to a computer-aided design (CAD) system as starting point for detailed design, simulation and optimization.

9:40 a.m.	V. Pushenko, V. Klepikov, V. Brjukhovetski, N. Kizilova, V. Litvinenko (UA-Kharkov)

A multiscale rheological model of superelastic metal alloys: from nano to macro scale

Some crystalline materials at high temperatures demonstrate superplasticity that is a state at which the material deforms well beyond its usual breaking point (~200%). In this state any treatment of the material like stamping, cutting, extension or rolling is easy and the constructions with lightweight design can be built. In this paper a novel multiscale rheological model of the superplastic material is proposed. At the microscale the shear deformations of the smaller grains on the surface of the greater ones have been modeled by rotations of the grains governed by the shear stress, adsorption, nanoscale friction and sliding within the discrete four-field micropolar model. At the mesoscale the dislocation model has been applied to describe the dislocations and agglomerations of the generalized grains with gradual development of the microstructure without or with defects.

10:00 a.m.	V. Wesling, R. Reiter, J. Hamje, T. Müller (D-Clausthal)

High Temperature Particle Jet Erosion of Nickel- and Cobalt-based Alloys

Higher operating temperatures can increase the effectiveness of different technical processes, e.g. turbines, combustion furnaces and cyclone separators. The combination of the increased temperatures with the stresses and strains necessitate new hardwearing materials. The research of the influence of high temperatures and oxidation on the wear resistance has mainly been conducted on single-phase materials.

In the current research, the influences of temperature, impact angle and kinetic energy of the particles are examined. Therefore, high temperature particle jet erosion tests of a nickel-based and a cobalt-based alloy were conducted. Hastealloy® C22 and Ultimet® Alloy were chosen, due to the high resistances against both corrosion and abrasion. The specimens are PTA-welded layers on steel plates, partially reinforced with different carbides, including fused tungsten carbides and titanium carbides. Initially, only carbides of the same grain size were used. Further tests were conducted on alloys with a mixture of carbides, varying in type and size. These tests were conducted in a specially designed testing machine with a variety of parameters. This includes temperatures of 750 °C, different particle velocities and impact angles. Oxidation tests were used to isolate the influence of the corrosion on the wear resistance at high temperatures. The results of this research provide a better understanding of the properties and capabilities of the alloys and carbides.

10:20 - 10:40 a.m. Coffee break and Visits of Expositions

12:00 noon – 1:30 p.m. Lunch and Visits of Expositions

12:00 noon – 1:30 p.m. Poster Session | Foyer Humboldtbau

L. Günther, F. Becker, T. I. Becker (D-Ilmenau), G. V. Stepanov (RU-Moskau), K. Zimmermann (D-Ilmenau)

Development of an acceleration sensor incorporating a magneto-sensitive elastomer

The present paper introduces an operating principle and concept of an acceleration sensor with an adaptable measuring range and sensitivity basing on the adjustability of the material properties of magneto-sensitive elastomers. The development of such a sensor requires a comprehensive understanding of the behaviour of the utilized material. Therefore, the magnetic field dependent behaviour of magnetic hybrid elastomer (MHE) with embedded magnetically soft and hard particles is investigated. Free vibrations of MHE beams are executed and hereafter, the frequency and damping behaviour are established. It is shown that the change of the magnetic field caused by a vibrating MHE beam contains detailed information about its deflection.
Basing on the revealed results, the acceleration sensor concept incorporating a functional MHE element is presented. The possibility to adjust the material properties of this element with an externally applied magnetic field is used.

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Workshops

WS 1 | Living Glass Surfaces
WS 2 | Virtual Reality
WS 3 | Digitale Mehrkanalbildverarbeitung und -erfassung
WS 4 | Neuartige Anwendungen in der Präzisionskraftmess- und Wägetechnik

Workshop 1 Living Glass Surfaces IX

Time: Thursday, 14.09.2017
Location: Humboldtbau | Lecture Room 211/212
Chair: E. Rädlein (D-Ilmenau)

The workshop "Living Glass Surfaces IX" celebrates the 10 years of the group of inorganic-nonmetallic materials at TU Ilmenau. It comprises research topics on interfaces in and on glass with contribution on durability of glass surfaces, coatings and laser processing and crystallization. Participants from research institutes, university and industry are invited to join the discussion on current developments in glass application.	
1:30 p.m.	E. Rädlein (D-Ilmenau)
Begrüßung	
1:35 p.m.	St. Reiß (D-Ilmenau)
The influence of chemical and thermal strengthening procedures on the degradation of glasses	
2:10 p.m.	J. Westphalen (D-Ilmenau, Dresden)
Surface refinement of ultra-thin flexible glass with magnetron sputtering	
2:50 – 3:10 p.m. Coffee break	
3:10 p.m.	M. Seel, St. Müller-Braun (D-Darmstadt)
Kantenfestigkeit von Flachgläsern im Bauwesen	
3:50 p.m.	M. Emons (D-Mönchengladbach)
Neuentwicklungen bei den Trennmitteln für Floatglas	
6:00 p.m. Hotel "Tanne"	

Workshop 1 Living Glass Surfaces IX
Time: Friday, 15.09.2017
Location: Humboldtbau | Lecture Room 211/212
Chair: E. Rädlein (D-Ilmenau)

9:00 a.m.	I. Issa (D-Freiburg)
Metallisation of SHJ solar cells with the use of negative masks, enhanced by SiO2 capping layers	
9:40 a.m.	L. Pohle (D-Ilmenau)
Abscheidung von SnO Schichten mit Atmosphärendruckplasmajet	
10:20 - 10:40 a.m. Coffee break	
10:40 a.m.	S. Kasch (D-Jena)
Laserbearbeitung Glas	
11:00 a.m.	A.-M. Schwager (D-Jena)
Selektives Lasersintern von Quarzglaspulver – Erzeugbare Oberflächen-qualitäten und Nachbearbeitungsmöglichkeiten	
11:20 a.m.	U. Brokmann (D-Ilmenau)
3D Mikrostrukturierung eines fotosensitiven Glases mit FS Laserstrahlung	
11:40 a.m.	E. Rädlein (D-Ilmenau)
Closing remarks	
End of the Workshop **1:30 p.m. Excursion to "Volle Rose" | Ilmenau**	

Workshop 2 Virtual Reality in Product Engineering

Time: Thursday, 14.09.2017
Location: Ernst-Abbe-Center | Lecture Room 1337/38 | FASP
Chairmen: H. Drumm | C. Weber (D-Ilmenau)

1:30 p.m.	H. Drumm (D-Ilmenau)

Human Capture System for Virtual Reality Applications

In recent years, the use of virtual reality in our lab at the university has shown that there are some existing deficiencies with the professional VR-system. Our VR laboratory was designed only to visualize and make audible content. One of the shortcomings is the lack of possibility to record the users during the experiments. Therefore, it was not possible to check the results of the experiments in retrospect.
Another missing feature was the use of new technologies for interaction, e.g. voice recognition, body tracking, or gestures. Today's VR-applications require the use of very different user data for designing interactive events. Based on our experiences, we not only have tried to develop a system which attempts to monitor and record the user data, but also to use the data for the interactivity of the scene. In this paper, an experimental hardware and software system is to be presented, called "Human Capture System". This system allows for integration of various data sources like sensors or simple data streams.
Our strategic objectives of the development have been to create a hardware- and software system which is capable of integrating several technologies. The measured and processed data is used for controlling the content in the VR-applications as well as for observing the user during the experiment. At present, software is still in the prototyping phase, and the functions have to be improved and adapted to our constantly changing needs.

1:50 p.m.	M. Dubiago (D-Ilmenau)

On the Effectiveness of a Virtual Public Speaking Training: State Anxiety in Virtual Reality versus Real Life

2:10 p.m.	A. Mahboob, A. Liebal, Ch. Weber, H. Krömker (D-Ilmenau) St. Husung (D-Darmstadt)

A Method for Efficient and Task Oriented Configuration of Virtual Reality (VR) Models for the Analysis of Technical Systems

The development of products for today's competitive and rapidly changing market demands incorporation of digital methods and new technologies. An early evaluation of a product can help the product designer to gain better understanding of product behaviour in its later life phases. In this paper, we will focus on building the product's life phase specific environments inside VR for product evaluation. These will also include the life phase specific actor(s) and environment for the product. A new method based on a MBSE approach will be presented for the description of VR environments that can help to reduce the effort needed to create them. The behaviour modelling process based on SysML will be explained using an example model. Moreover, a complete overview of the VR environment configuration, its execution and interaction possibilities will be brought to light.

2:30 p.m.	A. Siegel, Ch. Weber (D-Ilmenau), A. Albers, D. Landes, M. Behrendt (D-Karlsruhe)

Application of Artificial Neural Networks for Editing Measured Acoustical Data for Simulations in Virtual Environments

Acoustic simulation tools are used and demanded by various groups of people. Architects and urban planners as well as product designers and engineers are interested in simulating the acoustical properties of buildings, machines or other products. Acoustic simulation techniques are continually evolving. The current trend is towards integrating forward-looking technologies like virtual reality (VR) into the simulation process. Common acoustical simulation tools, such as numerical methods, are computationally expensive and can't be applied in real time. This, however, is a mandatory requirement for VR-applications. For that reason, techniques based on measured acoustical data are often used for acoustic simulations in VR. However, various disturbance variables, such as interfering noise, can distort measurement results immensely. In this paper an Artificial Neural Network (ANN) is described which can be used for the post-processing of measured data. A concept specifically for the noise cancellation in acoustic measurement data is outlined.

2:50 – 3:10 p.m. Coffee break	
3:10 p.m.	Demonstration of results at the Flexible Audiovisual Stereo Projection Device (FASP) – Ernst-Abbe-Center

Discussion

End of the Workshop

Workshop 3 Digitale Mehrkanalbildverarbeitung und –erfassung

Time: Thursday, 14.09.2017
Location: Humboldtbau |Lecture Room 202
Chairman: G. Notni (D-Jena)

13:30 Uhr	M. Schellhorn, R. Fütterer, M. Rosenberger, G. Notni (D-Ilmenau)

Smart Parallel Spectral Imager based on heterogeneous FPGA System on Chip

In the last years, industrial image processing has been shifting to areas and tasks that are increasing in complexity. This results in new challenges in order to contrast features to be detected or evaluated. Systems for the acquisition and interpretation of multispectral images are thus becoming more and more interesting. A major issue is, depending on the sensor principle, the time to acquire this spectral data. FPGA (Field Programmable Gate Array) and in particular heterogeneous FPGA SoC (System-on-Chip) offer the possibility to accelerate these acquisition methods decisively. In addition to the image acquisition, it is also possible to calculate decisive preprocessing steps in the hardware. A frequently used algorithm for analyzing but also compressing hyperspectral data is the PCA (principal component analysis). This paper presents a research setup that combines a heterogeneous FPGA SoC with a 12-channel filter wheel camera. With the help of the device a parallel working PCA is to be integrated, which works distributed in hardware and software. The paper presents the concept for this implementation and the current state of development in the project. In addition, restrictions on the development of algorithms with hardware systems and the current distribution in hardware and software are discussed.

13:50 Uhr	R. Fütterer, M. Schellhorn, M. Hänsel (D-Ilmenau)

SoC-Based Real-Time Passive Stereo Image Processing Implementation and Optimization

Stereo Image Processing as a part of three dimensional image processing become more and more important for industrial measuring, quality assurance and industrial automation. While classical image processing get it features from an image plane, additional information is obtained in direction of the optical axis. In comparison to active stereo methods, which need a projector or laser source and scanning device, passive stereo need at minimum two images from different perspectives. The paper starts with the basics of passive stereo, required optical setup and electronics. Some Information about the implementation of a stereo IP core in the used Xilinx SoC FPGA embedded system given. The program flow in ARM core and FPGA is illustrated. To get a high performance image processing system, the optimization of the parameters and the implementation settings on the used FPGA is very important. A comparison of several core parameter setups is done. Finally, some ways for further optimization with new hardware technologies are given.

14:10 Uhr	M. Preißler (D-Ilmenau)

Automatic Feature Detection in Point Clouds

14:30 Uhr	L. Radtke (D-Ilmenau)
Adaptive Test Bench for Characterizing Image Processing Sensors	
14:50 – 15:10 Uhr Kaffeepause und Besichtigung der Ausstellung	
15:10 Uhr.	G. Notni (D-Ilmenau)
Round Table Discussion Digitale Mehrkanalbildverarbeitung ID2M	
Ende des Workshops	

Workshop 4 Neuartige Anwendungen in der Präzisionskraftmess- und Wägetechnik

Time: Thursday, 14.09.2017
Location: Humboldtbau | Lecture Room 211/212
Chairmen: T. Fröhlich | M. Kühnel (D-Ilmenau)

9:00 Uhr	M. Kühnel, T. Fröhlich (D-Ilmenau)

Neues hochauflösendes, miniaturisiertes und monolithisches Tiltmeter der TU Ilmenau

Mit einem Tiltmeter wird der Winkel zwischen dem Vektor der Erdbeschleunigung (Lotrichtung) und dem Normalenvektor der zu messenden Ebene bestimmt.
Neigungsmessungen mit Nanorad Auflösung sind unter anderem im Bereich der Geophysik, Geodäsie und der Präzisions-Kraftmess- und Wägetechnik von Bedeutung.
In den vergangen Jahren wurden an der TU Ilmenau Referenzneigungsmesssysteme (Tiltmeter) mit Nanorad Auflösung, einem sehr großen Messbereich von ± 9 mrad (± 0,5°) und sehr guter Linearität entwickelt. Diese Referenztiltmeter basieren auf der Messung von neigungsbedingten Querkräften, die auf hängend gelagerten Präzisionswägezellen wirken. Deren Nachteil ist die vergleichsweise große Komplexität der Mechanik, das hohe Eigengewicht und die hohen Herstellkosten.
Aus diesem Grund wurde ein vereinfachtes Tiltmeter entwickelt, welches nur aus zwei Bauteilen besteht: einer monolithischen Pendelmechanik und einem optischen Wegsensor. Mit dem Wegsensor wird eine Standardabweichung der Wegmessung von ~ 50 pm bei einer Messfrequenz von 10 Hz erreicht. Die Pendellänge beträgt 0,1 m, die Masse des Pendels ~ 60 g. Die damit theoretisch erreichbare Standardabweichung der Neigungsmessung von ~ 0,6 nrad bei 10 Hz Bandbreite wurde in Messungen mit dem neuen Tiltmeter nachgewiesen. Der Messbereich des neuen monolithischen Tiltmeters beträgt ~ ± 2 mrad. Durch die monolithische Bauweise wird eine sehr hohe Langzeitstabilität sowie eine reproduzierbare und einfache Fertigung und Justage angestrebt.

9:20 Uhr	A. Gebauer, K. U. Schreiber (D-Furth im Wald)

Große Ringlaser zur Vermessung der Erde

9:40 Uhr	U. Brand, R. Popadic, Z. Li, S. Gao (D-Braunschweig)

Kalibrierung der Biegesteifigkeit von AFM-Cantilevern mit Kompensationswaagen

Rasterkraftmikroskope (AFM) werden in der Nanometrologie nicht nur für hochauflösende dimensionelle Messungen, sondern auch für hochauflösende mechanische Messungen, bspw. des E-Moduls oder der Härte von Nanoobjekten, eingesetzt. Die für diese Messungen benötigte Antastkraft wird dabei durch Multiplikation der Cantileverauslenkung mit der Biegesteifigkeit des Cantilevers berechnet. Standardmäßig wird die Biegesteifigkeit in vielen AFMs mit Hilfe der Thermal Vibration Methode bestimmt, die erfahrenen Nutzern Unsicherheiten der gemessenen Biegesteifigkeit bis auf 20 % erlaubt.

Neben diesem Verfahren sind in der 2015 erschienen ISO Norm 11775 weitere Methoden zur AFM Biegesteifigkeitsbestimmung aufgeführt. Wird eine geringere Unsicherheit der gemessenen Kraft benötigt, können vom Hersteller kalibrierte Cantilever mit Unsicherheiten der Biegesteifigkeit von 10 % kommerziell erworben werden. Noch kleinere Unsicherheiten werden bei der Kalibrierung der Biegesteifigkeiten von AFM-Cantilevern mit Kompensationswaagen erhalten.
Der Beitrag beschreibt die Messeinrichtung der PTB, eine Vergleichsmessung mit einer von der TU Ilmenau verbesserten Messeinrichtung, bei der die Auslenkungsmessung der Cantilever laserinterferometrisch erfolgt und stellt die erzielten Messunsicherheiten vor.

10:00 Uhr	R. Wenig, M. Kühnel, T. Fröhlich (D-Ilmenau)

Konstruktive Gestaltung des optimierten Positionier- und Kraftmesssystems der TU Ilmenau zur Kalibrierung von Federkonstanten von Mikrokraftsensoren

An der TU Ilmenau wurde ein Prototyp eines neuartigen Positionier- und Kraftmesssystems entwickelt, welches die rückführbare Kalibrierung der Federkonstanten (Kraft-Weg-Kennlinie) von Mikrokraftsensoren, Tastern oder AFM Cantilevern auf Basis einer Kraft und einer Wegmessung erlaubt. Aufgrund der integrierten interferometrischen Auslenkungsmessung der Cantilever, sind die mit der Messeinrichtung erreichten Messunsicherheiten mit < 2 % geringer als bisher im Stand der Technik beschrieben. Gemeinsame Vergleichsmessungen mit der Physikalisch-Technischen Bundesanstalt (PTB) haben dies bestätigt.
In Kooperation mit der PTB, die langjährige Erfahrung auf dem Gebiet der Cantileverkalibrierung besitzt, wurde die Messeinrichtung weiter optimiert. Dabei wurde der weiteren Reduzierung von Unsicherheitsbeiträgen der Wegmessung besondere Beachtung geschenkt. Des Weiteren erfolgten Optimierungen, die es möglich machen, ein noch breiteres Spektrum an Sensoren kalibrieren zu können.
Der Beitrag beschreibt die aus den Anforderungen abgeleitete konstruktive Gestaltung des optimierten Positionier- und Kraftmesssystems der TU Ilmenau.

10:20 - 10:40 Uhr Kaffeepause und Besichtigung der Ausstellung

10:40 a.m.	O. Dannberg, M. Kühnel, T. Fröhlich (D-Ilmenau)

Unsicherheitsbeiträge der Krafteinleitung bei der Kalibrierung der Federkonstanten von AFM Cantilevern

Die Kalibrierung der Federsteifigkeit von AFM Cantilevern, sowie Mikrokraftsensoren mittels Messung ihrer Auslenkung in Abhängigkeit einer eingeleiteten Kraft, gewinnt seit einigen Jahren zunehmend an Bedeutung. Die Kalibrierkräfte liegen dabei bei wenigen (Sub-) Mikronewton. Nur mit dieser Kalibriermethode können aktuell Messunsicherheiten der Federsteifigkeit von < 4 % erreicht werden. Auch an der TU Ilmenau wurde ein Positionier- und Kraftmesssystems entwickelt, welches die rückführbare Kalibrierung der Federkonstanten (Kraft-Weg-Kennlinie) von Mikrokraftsensoren, Tastern oder AFM Cantilevern auf Basis einer Kraft und einer Wegmessung erlaubt. Durch die interferometrische Auslenkungsmessung der Cantilever, werden mit der Messeinrichtung Messunsicherheiten von < 2 % (k = 2)

erreicht. In den genannten Publikationen wird die Ausrichtung des Cantilevers bzgl. der Kalibrierkraft bzw. des Krafteinleitungssystems als ein wesentlicher Beitrag zur Messunsicherheit aufgeführt. Hier wird auf Basis von einfachen Abschätzungen davon ausgegangen, dass die Fehlausrichtung zu reibungsbedingten Lateralkräften führt, die zusätzliche Verformungen des Cantilevers und damit Messunsicherheitsbeiträge von bis zu 2 % (k = 2) bedingen. In dieser Veröffentlichung werden die Beiträge der Fehlausrichtung der Cantilever auf Basis von analytischen und numerischen Modellen beschrieben sowie mit geeigneten Messungen überprüft. Das Ziel ist die Reduzierung der Messunsicherheit der Federsteifigkeit.

11:00 Uhr	G. Krapf (D-Ilmenau)

Modulare Elektronik zur digitalen Regelung von EMK-Systemen - Eigenschaften, Anwendungen und Potenzial

PC-basierte Regelsysteme bieten nicht nur hinsichtlich der Entwicklung, Erprobung und Optimierung von Reglern für komplexe elektromechanische Systeme, wie beispielsweise Kraftmesswandler und Waagen nach dem Prinzip der elektromagnetischen Kraftkompensation (EMK), erhebliche Vorteile. Insbesondere die leichte Implementierung, Anpassung und Parametrisierung von Regelalgorithmen höherer Ordnung sowie die Möglichkeit einer umfassenden Diagnose und Protokollierung in Echtzeit erweisen sich hierbei als äußerst nützliche Werkzeuge. Vor diesem Hintergrund wurde von der IKWI-Forschergruppe innerhalb des vom BMBF geförderten Projektes "InnoProfile-Transfer" eine modulare Mess- und Regelelektronik entwickelt, die speziell an die gehobenen messtechnischen Anforderungen von EMK-Systemen angepasst wurde.
Im Rahmen des Workshop-Beitrages werden der Funktionsumfang und die Leistungsfähigkeit dieses neu entwickelten "PC-in-the-Loop"-Regelsystems sowie seiner Hard- und Softwarekomponenten anhand experimentell ermittelter Messreihen diskutiert. Darüber hinaus werden alternative Nutzungsmöglichkeiten als Hardware-Simulator für EMK-Waagen, Trägerfrequenzverstärker für Kraftmesswandler mit Dehnmesstreifen und als Prototyping-Plattform für SoC-FPGA-Regelsysteme vorgestellt. Ferner wird das Potenzial hinsichtlich künftiger Weiterentwicklungen sowie Anwendungsfelder erörtert.

11:20 Uhr	N. Schröder (D-Erfurt)

On-Board-Weighing – Neuartige Kalibriermöglichkeiten

Das Wiegen von Gütern direkt auf einem Fahrzeug bringt enorme Vorteile mit sich. Die Gewichte stehen sofort an der Stelle zur Verfügung an der sie benötigt werden. Eine große Frage die dabei aufgeworfen wird ist allerdings die Kalibrierung der Fahrzeuge. Da viele der Fahrzeuge im Geschäftsverkehr eingesetzt werden, müssen Verfahren verwendet werden die einer kritischen Prüfung der Eichbehörden standhalten.
Des Weiteren ist es von großem Vorteil, wenn das Fahrzeug zur Kalibrierung nicht in eine Werkstatt, sondern an Ort und Stelle kalibriert werden kann. All diese Punkte werden in einem neuartigen Kalibrierverfahren der PAARI Group in Zusammenarbeit mit der TU Ilmenau zusammengeführt.

12:00 – 13:30 Uhr Mittagessen und Besichtigung der Ausstellung
12:00 – 13:30 Uhr Poster Session | Foyer Humboldtbau

Ende des Workshops

Ehrenkolloquium in memoriam an Prof. Eberhard Kallenbach

(1935 – 2016)

Ehrenkolloquium in memoriam an Prof. Eberhard Kallenbach

Time: Wednesday, 13.09.2017
Location: Humboldtbau | Audimax
Chairman: T. Ströhla (D-Ilmenau)

13:30 Uhr	P. Kurtz (D-Technische Universität Ilmenau)
Laudatio	
13:50 Uhr	R. Herrmann (D-Kendrion Mechatronics Center GmbH)
Der Elektromagneteentwurf und das Steinbeis-Transferzentrum Mechatronik	
14:10 Uhr	G. Blank (D-LPKF SolarQuipment GmbH)
Entwicklung von Linearantrieben, das Technikum Suhl und LPKF	
14:30 Uhr	N. Gorbatenko (RUS-SRSPU Novotscherkassk)
40 Jahre der erfolgreichen Partnerschaft zwischen der Technischen Universität Ilmenau und der Südrussischen Staatlichen Polytechnischen Universität Novotscherkassk (NPI)	
14:50 – 15:10 Uhr Kaffeepause	
15:10 Uhr	S. Kovalev (D-Technische Hochschule Mittelhessen)
Planarantriebe und magnetisches Schweben	
15:30 Uhr	J. Zentner (D-HTWK Leipzig)
Triplanar und Asynchrone Mehrkoordinatenantriebe	
15:50 Uhr	M. Klöpzig (D-Siemens AG)
Hochintegrierte Antriebssysteme in der Elektromobilität	
16:10 Uhr	T. Ströhla (D-Technische Universität Ilmenau)
Die Geschichte der Elektromagnete	

Social Events

Welcome Reception
Academic Gala Concert
Excursion and Banquet

Welcome Reception

Monday, 11.09.17, 5:00 p.m.

Before the Academic Gala Concert starts, all lecturers, participants and guests are kindly invited to a short Welcome Reception. The reception will be held immediately after the sessions.

Weather permitting, the welcome reception will be given on the square in front of the Humboldt Building. Otherwise, our guests are kindly asked to go inside.

Please Notice

The catering and beverage tickets must be shown, when you join the Thuringia's gastronomic specialities for free.

Please enjoy Thuringia's hospitableness.

Social Events

Academic Gala Concert

Monday,
11.09.17, 7:30 p.m.
Humboldtbau | Audimax

All lecturers, participants and guests are kindly welcome to the Academic Gala Concert.

Programme

The Leipzig Brass soloists
(Leipziger Blechbläsersolisten) performs

- **Richard Wagner** 'Einzug der Gäste auf der Wartburg'
- **Andrea Grossi** 'Canzona (Doppelchor)'
- **Giovanni Gabrieli** 'Toccata Athalanta'
- **Johann S. Bach** 'Air', 'Brandenburgisches Konzert Nr. 3'
- *Break*
- **Georg Friedrich Händel** 'Einzug der Königin von Saba'
- **Traditional** 'Londonderry Air'
- **Hoagy Carmichel** 'Stardust'
- **Jim Parker** 'Ein Londoner in New York'

Admission for tickets

Evening Box office:

- 20.00 euros/ticket (Standard)
- 19.00 euros/ticket (reduced fee for Students, pensioners, disabled persons)
- 10.00 euros/ticket (Childs)

The invoice will be given to you via email.
Your concert tickets will be handed out in the conference office.

Excursion and Banquet

Tuesday, 12.09.17, 4:00 p.m.

Coaches depart from the Refectory (Mensa Dining Hall) for the Excursion to Traces and Places of the Bach Family in the historic Residence Town of Arnstadt.

4:30 p.m. (approx.) Start: Markt 1, Arnstadt

Come and follow the traces of the Bach family through the narrow alleys of the old town in an amusing and imaginary guided tour. You will learn about the work and life of Johann Sebastian Bach who already in his young years was accepted as the organist in Arnstadt.

At the end of the circuit, you will enjoy Bach's music at the place of origin now called Bachkirche.

About 7:00 p.m.

The conference dinner will take place in the charming historic atmosphere of the "Stadthaus Hotel". All meals will be prepared based on regional organic foodstuffs of high quality.

Admission

for Participation in the Excursion with Banquet: € 45.00 (The price includes € 37.82 net and 19% VAT – € 7.18)

The price covers the journey by coach, the guided city tour, the organ concert and the conference dinner with welcoming drink.

More detailed information is available at: **www.stadthaus-arnstadt.de**

Notice

Please collect your admission ticket in the Conference Office. You will be asked to show it when getting on the coach.

List of Main Authors | Chairmen

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